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International Research Council

Conseil International de Recherches

SECOND REPORT
of the Commission
appointed to further the study
of

SOLAR AND TERRESTRIAL RELATIONSHIPS

DEUXIÈME RAPPORT
de la Commission
instituée pour poursuivre
l'étude des

RELATIONS ENTRE LES PHÉNOMÈNES SOLAIRES ET TERRESTRES

Étienne CHIRON, Éditeur
40, Rue de Seine, PARIS (VI·)

1929

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NOTICE

The Commission was appointed provisionally by the Executive Committee of the International Research Council in June, 1924, and originally consisted of :

ABBOT, C. G.
CHAPMAN, S. (Chairman).
DESLANDRES, H.
FERRIÉ, G.
SIMPSON, G. C.
St-JOHN, C. E.
STÖRMER, C.

The Commission was given power to add to their number.

In October, 1924, C. Chree, then President of the Section of Terrestrial Magnetism of the International Union for Geodesy and Geophysics, was added to the Commission at the request of the Section.

The Commission presented a first Report to the International Research Council in 1925, July, when the nomination of the Commission by the Executive Committee was confirmed.

The Commission was reappointed for three years, with the addition of G. ABETTI.

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Second Report to the International Research Council

1. Publication of the first Report

The Commission provisionally appointed by the Executive Committee of the Council in June 1924 presented its first Report to the International Research Council in July 1925. This report, which reviewed the state of knowledge of solar and terrestrial relationships at the time, also made various recommendations with a view to extending that knowledge. Together with :

(i) A number of memoranda by various authors on different branches of science coming within the scope of the Commission's work, and

(ii) A summary and bibliography of recent papers on solar relationships with meteorology, prepared by Dr. C. E. P. Brooks in continuation of the bibliography by Drs. Helland-Hansen and Nansen,

the first report was published in book form in 1926, by means of a grant made to the Commission for this purpose by the Executive Committee of the Council. Seven hundred and fifty copies of the Report were printed, and the majority of these were distributed to scientific Libraries, Institutions, and individual investigators ; the distribution was made in co-operation with, and partly by, the Secretaries of the International Unions of Astronomy, Geodesy and Geophysics, and Radio-telegraphy. A few copies of the first Report are still on hand.

2. Regulations for the constitution of the Commission

When, in July 1925, the Council confirmed the Commission as provisionally nominated, and reappointed it for three years (with the same personnel as before, save for the addition of Dr. G. Abetti), the Commission was directed to prepare, " in collaboration with those interested in the field ", " regulations

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for a suitable form of standing organisation " to fulfil the duties for which the Commission was constituted. In accordance with this request the Executive Committees of the International Unions for Astronomy and for Radio-telegraphy, and the Sections of Terrestrial Magnetism and Electricity, and of Meteorology, of the International Union for Geodesy and Geophysics, were consulted in the matter. The replies received appeared to indicate a desire that the Commission should be continued, and that the various International Unions concerned should be consulted regarding the membership of the Commission.

In consequence the Commission propose that, if the International Research Council sees fit to continue the Commission :

(I) Each of the following bodies be invited to name representatives, to the number stated, for appointment to the Commission by the Council :

(a) The International Union for Astronomy : two representatives.

(b) The International Union for Radiotelegraphy : one representative.

(c) The Section of Terrestrial Magnetism and Electricity of the International Union for Geodesy and Geophysics : one representative.

(d) The Section of Meteorology of the International Union for Geodesy and Geophysics : one representative.

(II) The Commission should consist of persons so appointed, together with others whom, from a survey of the whole field, the Council deem it desirable to appoint : the total membership of the Commission should, however, not exceed twelve.

(III) The Council should appoint the Commission for a period of three years at a time, reviewing and, if necessary, revising its composition at the end of each such period.

(IV) The Commission should have power to add to their number during their period of appointment, subject, however, to the specified total number not being exceeded.

(V) The Chairman of the Commission should be appointed by the Council.

The Commission regard it as desirable that the Chairman should not hold office for more than two successive three-year periods.

If the above proposals are accepted by the Council, the Commission recommend that, as a transitional measure, its present period of appointment be extended to 1928 December 31,

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to enable the above bodies to be consulted. Succeeding Commissions could then be appointed for successive periods of three years from 1929 January 1, and be directed to present their final reports to the Council in or about the month of July of their last year of appointment, when also the Council could again consult the above bodies as to their representation on the succeeding Commission.

3. Action taken on the first Report

(i) The recommendations made in the first Report mainly dealt with the need for further observations of various kinds and in different countries: particularly with the need for more magnetic and auroral observations at stations in or near the auroral zone, and for further measurements of the amount and distribution of solar radiation, and its absorption in the earth's atmosphere. These and similar recommendations were communicated through the General Secretary of the International Research Council to the Governments and national research organisations concerned: the time since elapsed has been too short for it to be possible to report any definite action as a result of the recommendations. Progress has, however, been made in some of the suggested directions, notably by the establishment of a magnetic observatory at Godhaven, Greenland, by the Government of Denmark: by the foundation of a magnetic and auroral institute at Tromso, Norway, with the aid of the Rockefeller International Education Board: by the establishment of a new solar radiation observatory in South-West Africa by the Smithsonian Institution; and by the extension of the magnetic equipment of the Meanook Observatory in Canada. Discussion is proceeding in America as to the possibility of organising auroral observations at Fairbanks, Alaska (57° 3' N, 135° 20' W).

(ii) The Commission recommended that the International Union for Astronomy be asked to organize a scheme for the characterization of successive Greenwich days (from midnight to midnight) according to the state of the sun with respect to one or more of its variables. In conjunction with the magnetic character figures already internationally assigned, such solar character figures would greatly facilitate the study of solar relationships with terrestrial magnetism. This recommendation was considered by the International Union for Astronomy at its meeting at Cambridge in 1925, and was referred to a Committee of the Union: the Report of this Committee has been considered at the Leiden (1928) meeting of the Union, and a provisional scheme has been prepared *. It is proposed that a bulletin shall be issued bimonthly or quarterly by the Observatoire Fédéral, Zürich, giving daily

*See p. 7 of this volume.

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character figures for four separate solar phenomena. These have been chosen as being those most likely to show correlation with the terrestrial phenomena which appear to depend on solar emissions projected in limited streams. Hence the character figures will refer to the state of the sun (in these four different respects) within a limited central sector of the sun's disc.

(III) The Commission recommended that Dr. L. A. Bauer, the Secretary of the Section of Terrestrial Magnetism and Electricity of the International Union for Geodesy and Geophysics, be asked to formulate a scheme for a service to supply information to solar observatories as to magnetic storms, in progress or prospective (in accordance with the 27-day recurrence tendency). As a result of conferences which he held with Drs. Hale, Adams and Nicholson of the Mount Wilson Solar Observatory, it was decided first to make trial investigations there, and a horizontal force magnetograph was installed for the purpose. The records will be compared in detail with solar phenomena, and it is hoped that in due course it will be possible to decide whether and in what manner current information as to magnetic phenomena can usefully be supplied to solar observatories.

4. Memoranda on recent progress

Attached to the present Report there are numerous memoranda, contributed by members of the Commission and by other investigators at their request, which describe recent work on various aspects of solar and terrestrial relationships. While the Commission does not hold itself collectively responsible for the opinions and conclusions expressed in these memoranda, which in some cases necessarily deal with controversial matters, it regards the memoranda as evidence of great and fruitful activity during the past few years in many subjects bearing on solar and terrestrial relationships. On account of the wide variety of th se investigations, and the desirability that workers in these fields should have information as to work in cognate branches made readily accessible to them, the Commission recommends the publication and distribution of the Memoranda with this Report.

5. Solar relationships with terrestrial magnetism

(a) In regard to terrestrial magnetic observations, the chief need continues to be that of further continously-recording magnetic observatories in high magnetic latitudes. The Com-

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mittee considers it desirable that new continously-recording magnetic observatories be instituted at

(i) Jan Mayen or Spitsbergen,
(ii) North-eastern Canada,
(iii) Northern Alaska, additional to and to the north of, the existing observatory at Sitka,
(iv) Northern Russia and Siberia.

(b) The Committee considers it desirable that the daily character figures for magnetic disturbance be supplemented by daily character figures relating to the amplitude of the portion of the daily magnetic variation which is of quiet-day type, as representing a separate phenomenon varying independently of the degree of magnetic disturbance.

6. Solar relationships with auroræ

The Committee considers it desirable that regular auroral observations, preferably photographic, be made at as many points as possible around the auroral zone, and recommend the plan of observations outlined by the Committee appointed at Prague by the Section of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics, to prepare an atlas of auroral forms and a scheme of observations based thereon*. Observatories such as are recommended under (5_a) would be specially suitable for such observations.

The Committee note the advance recently made by McLennan and his associates in the definite identification of the green auroral line as due to atomic neutral oxygen †, and anticipate considerable further accessions to our knowledge of the manner in which the upper atmosphere is affected by solar emanations as a result of further observations and laboratory study of the auroral spectrum.

7. Solar relationships with meteorology

(a) The Committee regards the regular detailed observation of :

(i) the amount and spectral distribution of the total solar radiation and,
(ii) of the absorption in the earth's atmosphere, particularly by ozone,

as of primary importance.

(b) The Committee consider it desirable that regular observa-

* This scheme of observations is printed on p. 127, of this volume.
† Cf. p. 27.

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tions of this kind should be made at observatories, preferably situated at a high altitude, in the following regions :

(I) Australia.
(II) Europe.
(III) India.
(IV) Indo-China.
(V) Japan.

(c) The Committee note the important step made by the institution of regular daily measurements of the intensity of the sun's ultra-violet rādiation at Mount Wilson and Tucson observatories, and consider it important that intensity-figures for this radiation on each day be regularly published for comparison with magnetic and other data.

(d) The Committee note the important advances recently made in our knowledge of the ozone-content of the upper atmosphere and its variations, by Profs. Fabry* and Buisson and their fellow-workers in France, and by Dr. Dobson† and those who have co-operated in his scheme of systematic observations in England and many other parts of the world. They consider that the variations are of great interest from the standpoint of solar and terrestrial relationships, and that regular observations of the ozone-content of the atmosphere should continue to be made, and should be put on a permanent basis, by the adoption of these observations, including their reduction, as a part of their regular programme, by a number of existing observatories, well distributed over the world.

(e) The Committee note that the existence of a temperature of about 300° absolute at about 50 kilometres height in the atmosphere, deduced by Lindemann and Dobson from their theory of meteors, has been confirmed in an independent way by the study of the propagation of sound to great distances‡, the sound-waves being refracted downwards in the warm upper layer; and also† at Gowan, by the study of the absorption of solar radiation by the ozone known to exist in the upper atmosphere, has shown that such temperatures can be theoretically accounted for†. The measurement of the time of propagation of sound to great distances, and the determination of the inclination of the down coming waves permit the estimation of the temperature of the atmosphere at a height inaccessible to direct observation. As the temperature at such heights seems likely to be more directly controlled by variations of solar radiation than is the case at lower levels, the Committee consider it desirable that this new method of investigation be pursued systematically in Europe, America and elsewhere, in order that the temperature and its variations may be determined in different regions of the globe, and particularly over a wide range of latitude.

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* Cf. p. 49 † Cf. p. 44 ‡ Cf. p. 114 † Cf. p. 62.

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8. PUBLICATION OF SOLAR DAILY CHARACTER FIGURES

It is recommended that a grant not exceeding forty pounds sterling per annum be made for three years to the Observatoire Fédéral, Zürich, for the publication of the proposed bulletins (item 3. II of this Report) giving for the period 1928 January 1st to 1930 December 31st daily character figures for various solar phenomena whose correlation with terrestrial phenomena it is desired to examine.

REPORT OF THE SUB-COMMITTEE APPOINTED BY THE SOLAR PHYSICS COMMISSION TO PREPARE A SCHEME FOR THE ASSIGNMENT OF SOLAR CHARACTER FIGURES TO EACH GREENWICH DAY

(a) It is desired to have simple character figures for various solar phenomena referring to each Greenwich day from midnight to midnight, for the purpose of examining the relationship between terrestrial and solar phenomena, particularly with respect to those terrestrial phenomena which appear to depend upon corpuscular emissions projected from the sun in limited streams. Hence the figures should refer to the state of the sun's surface which, at or about noon on each Greenwich day, is situated between meridians lying 30° on either side of the central meridian of the sun.

(b) It is recommended that the characteristic figures be assigned for each of the following solar phenomena :

(1) Relative sunspot numbers assigned on the same lines as for the Wolf numbers, except for the limitation to the central sector of the sun's disc : to be assigned at Zürich.

(2) The Calcium flocculi.

(3) The bright Ha flocculi.

(4) The dark Ha flocculi.

The character figures for phenomena (2, 3, 4) should be assigned* on a scale of numbers 0, 1, 2, 3, 4, 5. The numbers

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*At Zürich, on the basis of character figures individually contributed by various solar Observatories, including Arcetri, Cambridge, Coimbra, Ebro, Ewhurst, Kodaikanal, Madrid, Meudon and Mount Wilson.

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should refer to the area and intensity of the flocculi, 0 representing absence or rarity of flocculi, and 5 extreme abundance and intensity.

(c) On days when any of the phenomena (2, 3, 4) show unusual features, such as great activity of change or unusual brilliancy, this should be indicated by a special footnote.

(d) It is recommended that these character figures should be published quarterly or bi-monthly for the period beginning 1928 January 1st, by the Observatoire Fédéral, Zürich, in a special bulletin.

(e) It is recommended, as a matter of convenience, that this bulletin should give for each Greenwich day, in addition to the above character figures referring to a limited sector of the sun's disc, the following solar numbers referring to the whole solar disc :

(5) The Wolf complete relative sunspot number.

(6) The intensity of the ultra-violet radiation as measured at Mt. Wilson.

(7) The solar constant as measured by the astrophysical observatory of the Smithsonian Institution.

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ON THE CONNECTION BETWEEN SOLAR ERUPTIONS AND TERRESTRIAL MAGNETIC STORMS

by

GIORGIO ABETTI

A study of the relations between the phenomena of solar activity and terrestrial magnetic disturbances tends more and more to support and strengthen Tacchini's hypothesis which was later confirmed by Hale.

In fact Tacchini clearly expresses himself as follows : (1)

> " ... if a large spot when crossing the disc is followed by a magnetic disturbance on the earth, it means that that spot and the regions around it were subjected to extraordinary phenomena, such as prominences, solar eruptions, auroræ, etc., these give rise to the above mentioned disturbance ; on the other hand if the earth's magnetism remains normal the large spot or group passed in a quiescent state ".

Hale has shown that the intensity of the magnetic field in spots decreases rapidly from the level of the photosphere towards the chromosphere and concludes (2) that it is improbable, as indicated by the theory,

> " that terrestrial magnetic storms are directly due to magnetic fields in sunspots. Their origin may be looked for, with greater hope of success, in eruptions, visible in spectroheliograms, affecting the regions surrounding the spots ".

It is only in a few isolated cases that the spectroheliograph has enabled us to establish, with some degree of probability, the connection between any definite solar eruption and a definite terrestrial magnetic storm. The scarcity of such observations is due to the relatively short period during which the spectroheliograph has been put to practical use in observatories, and also to the rapidity with which the phenomena develop, which makes it difficult to ascertain the actual moment of maximum activity and thus to establish with some degree of probability the connection between any given solar eruption and a given terrestrial magnetic storm.

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(1) Mem. Spettr. Ital. Vol. 23, p. 5, 1894.
(2) Astrophys. Jour. Vol. 28, p. 341, 1908.

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The object of this paper is to bring forward some of the more remarkable instances which confirm Tacchini's and Hale's hypotheses, and also furnish a probable value of the time taken by the disturbances to reach the earth from the sun.

The fact that solar influence on terrestrial magnetism lags behind the phenomena of solar activity has been frequently demonstrated by Ricco (1), who took, as the time of departure of the sun's disturbing elements, the instant when the large active spots crossed the sun's central meridian, this he considered the most favourable moment for the disturbing elements to strike the earth. Maunder (2), who undertook a vast statistical investigation of the presence of sunspots in relation to terrestrial magnetic storms, finds that the latter begin during a period which lies between 34 hours before and 36 hours after a group of spots has passed the sun's central meridian; the mean is 26 hours after. It would seem that there is a definite zone on the sun's disc which is most favourable to the appearance of terrestrial phenomena.

If the magnetic disturbances on the earth are due to swarms of corpuscles projected from limited regions of the solar surface surrounding the spots, it is evident that the corpuscles cannot reach the earth unless the regions are suitably situated, that is at such angles to the line of sight as may be obtained, according to Evershed (3), from Maunder's investigations. These angles should, in fact, seldom exceed 34° in longitude because the time interval mentioned above corresponds to a total angle of 68° in longitude. Taking the mean western position of the spots at the beginning of a magnetic storm, that is 26 hours west of the central meridian, this evidently corresponds to the time taken by the corpuscles to travel from the sun to the earth with a possible mean deviation east or west of 34° from the line of sight. It would therefore appear that the swarms of corpuscles are emitted from the spots or the surrounding regions in any direction with a mean velocity of 1600 km./sec., and within the limits of a cone of angle about 68°, whose apex is situated in the spot and whose axis lies in the direction of the sun's radius at that point.

These considerations are also confirmed by the relation which Cortie (4) has found between the presence of sunspots and magnetic storms when the heliographic longitude of the former is taken into account. He found that the position of a disturbed area on the sun's surface is more effective magnetically when, after a maximum, the latitude of the spot approaches the equator. Inasmuch as the earth's heliographic latitude varies between ±7°, it is then in the most favourable position to be influenced by solar disturbances. Cortie further observes

(1) Mem. Spettr. Ital. Vol. 33, p. 38, and Vol. 38, p. 157, 1909.
(2) M.N.R.A.S. Vol. 64, p. 205, 1904 and Vol. 65, p. 2, 1904.
(3) The Observatory. Vol. 27, p. 129, 1904.
(4) M.N.R.A.S. Vol. 73, pp. 52 and 539, 1912-1913, and vol. 76, p. 13, 1915.

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that it is because at these times the earth attains its maximum heliographic latitude and is therefore most favourably placed with respect to the regions of maximum sunspot frequency that magnetic disturbances are more frequent at the equinoxes. It is less influenced in June and December when the earth crosses the sun's equator. The phenomenon must there fore depend upon the inclination of the sun's axis to the plane of the equator, or in other words it is dependent on the earth being favourably situated, with respect to the sunspot zone, both as regards latitude and longitude.

That solar eruptions around the spots must be the cause of magnetic storms may be inferred from the fact that the storms often occur in waves, and further from an examination of the coronal rays during eclipses it may be concluded that solar influence on terrestrial magnetism is propagated in the shape of divergent rays emanating from definite foci in the disturbed solar regions.

We shall now examine some of the most typical observations of solar eruptions which are presumed to be directly connected with terrestrial magnetic storms.

The visual observations of Carrington and Hodgson of solar eruptions on 1st September 1859 and of Young on 3rd and 5th August 1872 are classic, these were accompanied by magnetic storms of considerable intensity. But the absence of complete records of the solar phenomena does not admit of a proper comparison of the terrestrial and solar phenomena. This has only been rendered possible later by Hale's invention of the spectroheliograph, which enabled him on 15th July 1892 (1) to photograph an eruption of exceptional brightness which changed rapidly both in intensity and form. W. J. S. Lockyer (2) who examined these records found that the time from the maximum of solar activity to the beginning of the magnetic storm and to its maximum was 21-34 and 25-34 hours respectively.

Another eruption which was followed with the spectroheliograph, presumably in its total development, was that of 10 th September (3) The observations showed two spots in opposite hemispheres connected by extensive masses of hydrogen. The whole phenomenon lasted less than four hours, and from the time of its maximum intensity to the beginning of the magnetic storm 26 h. elapsed. The maximum intensity of the magnetic storm occurred 43 hours after the solar eruption.

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(1) Astronomy and Astrophysics. Vol. XI, p. 917, 1892.
(2) M.N.R.A.S. Vol. 10, p. 18, 1919.
(3) Fox and Abetti. Interaction of sunspots. Astrophys. Jour. Vol. 29, p. 40. 1909.

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Spectrograms of a very active group of spots taken at South Kensington (1) with the calcium K line show the development of a considerable eruption. The solar phenomenon can also be followed on spectrograms taken by Slocum at the Yerkes Observatory : the maximum activity of the eastern group of spots may be said to have taken place at about 10 h. 5 m. G.M.T.; at 11 h. 11 m. the eruption was waning. A violent magnetic storm was recorded on the earth ; it began 26 h. later, and its maximum occurred 30 h. after the maximum of the solar eruption.

During the present maximum of solar activity other similar cases have been recorded with the spectroheliograph and observed visually by Hale with the spectrohelioscope.

In a series of spectroheliograms taken with lines H_a and K23 by Royds (2) at Kodaikanal on 22nd February 1926, filaments and flocculi much brighter than usual were observed above an active spot ; the maximum activity may be taken as having occurred at about 14 h. 30 m. G.M.T. On 24th February a magnetic storm affected the earth (3) ; it began 23 h. 30 m. after the solar eruption had reached its maximum, and 50 h. 30 m. later the storm reached its maximum intensity.

At the Meudon Observatory d'Azambuja and Grenat (4) obtained spectroheliograms in the line H_a of a group of spots which passed the central meridian on 15th October 1926 : above the group an exceptional eruption was taking place. In this instance too the phenomenon appears to have been a very rapid one, with maximum intensity at 13 h. 15 m. G.M.T. on 13th October. About an hour later, while the eruption was subsiding, the velocity-recorder showed descending masses of hydrogen whose velocity was of the order of 130 km./sec. A violent magnetic storm began 31 h. later and reached its maximum 56 h. after the eruption.

On 24th January 1926, Hale (5) observed visually with the spectrohelioscope an extensive eruption taking place over a large group of spots; this was followed by a magnetic storm and by a brilliant aurora borealis. As the instrument was still in the experimental stage, complete data are wanting to determine the time of maximum intensity. It is obvious that the extended use of the spectrohelioscope will provide a valuable supplement to the photographic records obtained with the spectroheliograph.

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(1) M.N.R.A.S., Vol. 70, p. 22, 1909.
(2) M.N.R.A.S., Vol. 88, p. 380, 1929.
(3) Nature, No 2942, p. 416, March 20, 1926.
(4) Bull. Soc. Astf. de France, 40e année, p. 489, 1926.
(5) Proc. Nat. Ac. of Sciences. Vol. 12, p. 290, 1926.

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Recapitulating the cases observed with the spectroheliograh and described above, we get :

Date of maximum activity of solar eruption.		Magnetic storm after solar eruption	
		Beginning	Maximum.
1892 July 15th.	5-7 h. G.M.T.	21-3 h.	25-3 h.
1908 Sept. 10th.	8-0 h.	26-0 h.	43-0 h.
1909 Sept. 24th.	10-6 h.	26-0 h.	30-0 h.
1926 Feb. 22nd.	14-5 h.	23-5 h.	50-5 h.
1926 Oct. 15th.	13-2 h.	31-0 h.	56-0 h.
	Mean	25-6 h.	41-0 h.

Although there is a considerable variation from the mean of 41 h. in the case of the time interval between the maximum activity of the solar eruption and the maximum intensity of the corresponding magnetic storm, perhaps due to the difficulty in determining the latter from the various magnetic measurements, yet the period of 25-6 h. for the interval to the beginning of the magnetic storm may be taken as determined with sufficient accuracy, especially as it agrees with the value obtained from the passage of spots across the central meridian. It therefore appears that observations of this nature provide a sufficiently accurate value of the velocity with which disturbances travel from the sun to earth, namely about 1600 km. /sec.

In an important theoretical study of the possibility of emission of atoms at high velocity from the sun, Milne (1) has calculated the limiting velocity with which they can pass out of the sun's gravitational field under the influence of radiation pressure. In the particular case of the Ca+ atoms, taking line K, he obtained a velocity of 1630 km. /sec., a result which is of the same order of magnitude for other elements such as H, He, Ti+, Sr+, Mg, and also for any others which are in a condition to be supported by radiation pressure in the chromosphere.

The agreement between the theoretical and observed values favours the hypothesis of the emission of swarms of atoms from the disturbed regions in the sun, giving rise to terrestrial disturbances when their path is such as to strike the earth.

In conclusion, we realise the importance of a systematic study of these phenomena : but while continuous records are kept of the earth's magnetism, in order to follow the activity of the sun we are, at any rate for the present, dependent upon such discontinuous observations as are possible with the spectroheliograph and spectrohelioscope. Hence the necessity of intensifying such observations in a large number of observatories suitably situated, both as regards climatic conditions and distribution in longitude (2).

(1) M.N.R.A.S. Vol. 86 p. 459, 1926.

(2) An excellent and complete résumé of solar physical research in 1926 has been published by D'Azambuja in the Bulletin of the Astronomical Society of France for April 1927. The eruptions and magnetic storms in the year 1926 and their mutual connection are discussed therein, and there is also special mention of the hypothesis advanced by Deslandres.

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VARIATIONS OF SOLAR RADIATIONS

by

Dr. C. G. ABBOT

The Smithsonian Institution continues to carry on its solar radiation station at Montezuma, Chile. The station formerly at Mount Harqua Hala, Arizona, was removed in November 1925, to Table Mountain, California (Lat. 34° 22' No., Long, 117°41' W., Altitude, 2460 meters). In December 1926, observations were begun at Mount Brukkaros, South West Africa (Lat. 25° 52' S., Long. 17° 48' E., Altitude 1706 meters) under Smithsonian direction, at the expense of the National Geographical Society. At all three of these stations the solar constant of radiation is being observed on every favourable day. The fundamental method of Langley is used frequently as a test, but on every observing day from one to five values are obtained by the short methods devised by Smithsonian observers, in which a measurement of the humidity and brightness of the atmosphere serves to estimate its transparency.

The increased number of observations per day, and the independence of the results of gradual changes of transparency during the series of observations, which are both favorable features of the short method, have together greatly diminished the accidental error. Thus the range of variation formerly ascribed to solar change has been much reduced. But even in monthly mean values there still remains, as found in the 9-year period over which excellent results at all seasons are now available, a range of solar constant values from 1.91 to 1.97 calories. Daily observations exhibit a total range still wider.

It appears that the monthly mean values march in general parallelism with the sun-spot activity. Superposed on this variation is a strong regular periodicity of 25-2/3 months. Also there are periodicities of lesser importance of about 15 and 11 months, and there are found also harmonic overtone periods of these three regular periodicities. These results have held as from 1920 to 1926 inclusive. If continued indefinitely in future they must have great interest (1).

A new test method based on pyrheliometry alone has been developed by C. G Abbot (2). By the application of it important corrections and improvements in the solar constant deter-

(1) See Smith. Misc. Coll. Vol. 80, No. 2, p. 8.
(2) See publication last cited, pp. 1 to 5.

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minations of Mount Wilson and Montezuma have been made Greater attention than formerly is being paid to the elimination of sky radiation near the sun.

With the completion of several years of continuous observing under comparable conditions, it has become possible to revise the methods of reduction employed, and to determine systematic errors by statistical comparisons. This work is completed for the Montezuma station, and it is believed that present publications of the results of that station, such as are now daily included in the weather map of the U.S. Weather Bureau, are definitive, and are given on the same scale as the results formerly published from Mount Wilson and Calama, Chile. Similar critical study is being carried to a completion for Table Mountain, California.

A revision of the Smithsonian data is being made after the accumulation of several years of homogeneous observations, and a further statement is deferred until the definitive results of this revision are fully available.

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SOLAR ACTIVITY AND WIRELESS TRANSMISSION

SOME THEORETICAL CONSIDERATIONS

by

E. V. APPLETON

It has been shown by L.W. Austin that there exists a direct correlation between solar activity and the strength of long-wave wireless signals when averaged over long periods. On the other hand G.W. Pickard, making signal intensity observations on broadcasting wave-lengths, has found an inverse relation between signal strength and sunspot numbers. It has been further found within the last few years that isolated magnetic storms supply evidence of a similar character, for, on such occasions, although there have been exceptional cases, the general rule is that short wave signals are weaker and longwave signals stronger. Such a difference in the effects on long and short waves is remarkable and, since these abnormalities are detectable in long distance transmission, for which cases the energy causing the signals is almost wholly borne by waves travelling through the atmosphere, we must look for an explanation of the difference in terms of the influence of the ionized regions in the upper atmosphere.

It seems most probable that there is a real physical difference in the processes by which long and short waves are returned from the upper atmosphere. For long waves the gradient of conductivity (or dielectric constant) at the lower boundary of the ionized region is most probably large enough within a wave length to produce true reflection. On the other hand the wireless evidence suggest that short waves are ionically refracted at much greater heights. Thus the short waves have to travel through the regions that are effective in deviating long waves back to the ground.

Let us now suppose that the effect of enhanced solar activity is to increase the ionization in the lower portions of the ionized regions. An increase in the specific conductivity of that region would result, so that there would be an increase in the intensity of the waves reflected from its surface. This would be accompanied, however, by an increased absorption of waves passing through it.

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It is possible to pursue the matter a little further. L.W. Austin and I.G. Wymore have shown that the signals from Nauen received at Washington are approximately 1.8 times as strong at sunspot maximum as at sunspot minimum. Now G.N. Watson has given a formula, which applies to long-distance transmission between two reflecting surfaces, and expresses the received signal intensity in terms of the aerial constants, the distance of transmission and the wave-length, and the resistivities of the upper atmosphere and the ground. Since the Nauen to Washington transmission is almost solely oversea we may safely neglect effect of the ground resistivity and assume that the attenuation is due to the resistivity of the ionized layer. By a calculation, which need not be reproduced here, it is possible to estimate the variation in the resistivity of the ionized layer necessary to account for the above-mentioned variation in the intensity of the Nauen signals. This calculation shows that the conductivity of the layer is 1.6 times greater at sunspot maximum than at sunspot minimum. It should be pointed out that we are here dealing with the specific conductivity of the lower layers of the ionized region responsible for deviating 13000 metre waves back to the ground, but t is interesting to note that S. Chapman has estimated that the otal conductivity of the layer as a whole is 1.5 times as great at sunspot maximum as at sunspot minimum.

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SOLAR ACTIVITY AND RADIO TRANSMISSION

by

L.W. AUSTIN

Signal Strength

Solar activity has long been suspected of playing a part in the changing conditions of radio transmission, both in regard to the strength of the signals and of the atmospheric disturbances. A connection between magnetic storms and radio telegraphy was first definitely established by Espenschied, Anderson and Bailey (1) during the work of the Bell Telephone Company for the establishment of a transatlantic telephone service. They found that magnetic storms often greatly decrease the strength of night signals and slightly increase the daylight strength. This effect is more pronounced at a wave length of 5000 m. than at 17000 m. Since terrestrial magnetism is known to be closely connected with solar activity, a similar connection of solar activity and radio signal strength is to be expected, and G.W. Pickard ((2) has more recently shown that such a relationship exists. In his papers he has described his own work on night signals in the broadcasting range and has also based calculations on the long wave daylight observations at the Bureau of Standards, and on the night observations of Dr. A. H. Taylor on the ultra-short waves. In these calculations he has made use of the moving avereges of the day by day observations and has paid special attention to 27-day periodic averages. Mr. Pickard's own observations indicate quite positively an inverse relationship between the strength of night signals in the broadcasting band and the sunspot numbers. The ultra short wave night signal material treated by the same methods has indicated, on the contrary, a direct correlation. This last conclusion is however seemingly not in agreement with a number of observations made by others of weakened ultra short wave night signals at times of great solar and magnetic disturbances.

Mr. C.N. Anderson (3) of the American Telephone and Telegraph Company has very recently published a paper which is

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(1) Proc. I.R.E. Vol. 14, p. 7, 1926.
(2) Proc. I.R.E. Vol. 15, pp. 83 and 749, 1927.
(3) Proc. I.R.E. Vol. 16, p. 297, 1928.

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an extension of the earlier work already cited, in which the trans-atlantic telephone experiments of this company covering wave lengths between 5,000 and 18,000 m. have been most carefully examined for evidences of correlation with solar activity and terrestrial magnetism. His conclusions are that while there s a close relation between radio signal strength and solar and

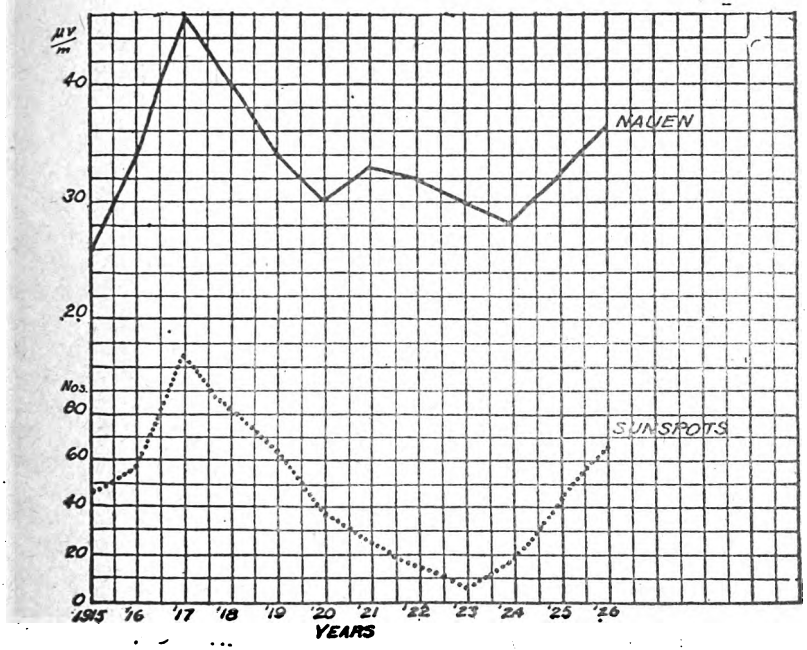

Fig. 1—Annual Average Signal Intensity of Nauen (AGS), 10 A.M. and Sunspot Numbers.

magnetic activity when averaged over long periods of time, the correlation is small when averaged in periods of less than about a month.

Rough observations on signal strength by the shunted telephone method were begun at the Bureau of Standards in 1915, and on the strength of atmospherics a little later; while since 1922, measurements have been made by more accurate methods (4).

In Fig. 1. the annual averages of sunspot numbers and the all-daylight reception from Nauen, Germany, in Washington from 1915 to 1926 are shown. The earlier years of the Nauen reception curve have little claim to accuracy, but it is reasonably certain that there was a reception maximum in 1917, and low values from 1920 to 1924. The signal curve is reduced to uniform antenna current.

(4) Proc. I.R.E. vol. 12, p. 521, 1924.

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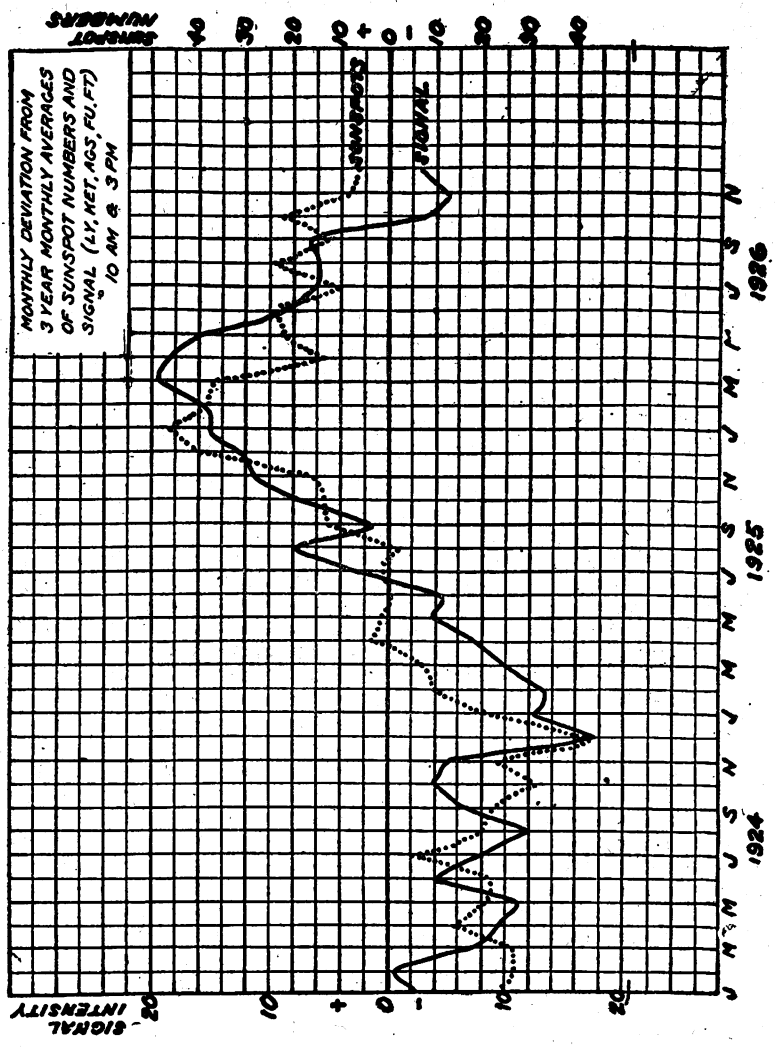

Fig. 2

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Fig. 2. shows curves for the monthly averages of the daylight signals of a number of stations and sunspot numbers from 1924 to 1926. In order to eliminate the effects of seasonal variations the observational points of the curves are the deviations from the mean values for the corresponding months for the three years. These curves of sunspots and signals in Figs. 1 and 2, while not following each other exactly, indicate a fairly definite connection between solar activity and the strength of long wave daylight transmission when averaged over long periods. The correlation coefficient in Fig. 2 is 0.74 ± 0.052.

In another place (5), similar monthly average curves have been shown indicating the regular rise of Nauen's daylight signals for the five years 1922 to 1926. Similar curves are also shown in another paper (6) for the Radio Corporation's transatlantic station (WGG) at Tuckerton, N.J., which is only 250 km. from Washington, indicating that great distance is not required for the effect to become evident.

Twenty-seven day averages of the daylight Nauen observations for 1925-1926 (6) at the Bureau of Standards indicate an inverse relationship between sunspots and signals, which would seem to be in contradiction to the direct relationship indicated by the annual and monthly averages just mentioned. This contradiction perhaps suggests that the sun's influence on transmission depends partly on the general condition of activity in the sun and partly on the position of certain areas, in respect to the earth, which may or may not be rich in spots.

Attempts to correlate the daily observations of signal intensity with the corresponding numbers of sunspots have never been very successful. There seems to be a tendency for the sunspot and signal curves to shift relatively back and forth in phase, as though at times there might be a lag in the appearance of the sunspots in respect to the fundamental solar disturbance producing them, while, on the other hand, there often seems to be a delay in the formation of the conditions in the earth's atmosphere which produce the changes in signal strength. By averaging the observations in periods of five days or more, fairly good agreement between the sunspots and long wave daylight signals is often found, which sometimes continues over long periods, so that notwithstanding the phase shifts already mentioned, the frequent similarity of the sunspot and signal curves renders it almost certain that we are dealing with a genuine relationship. On the whole, we may say that there seems to be about the same degree of correlation between signals and sunspots as between two signals of similar wave lengths received at a given receiving station from two separate transmitting stations.

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(5) Proc. I.R.E. Vol. 15, p. 825, 1927.
(6) Proc. I.R.E. Vol. 16, p. 166, 1928.

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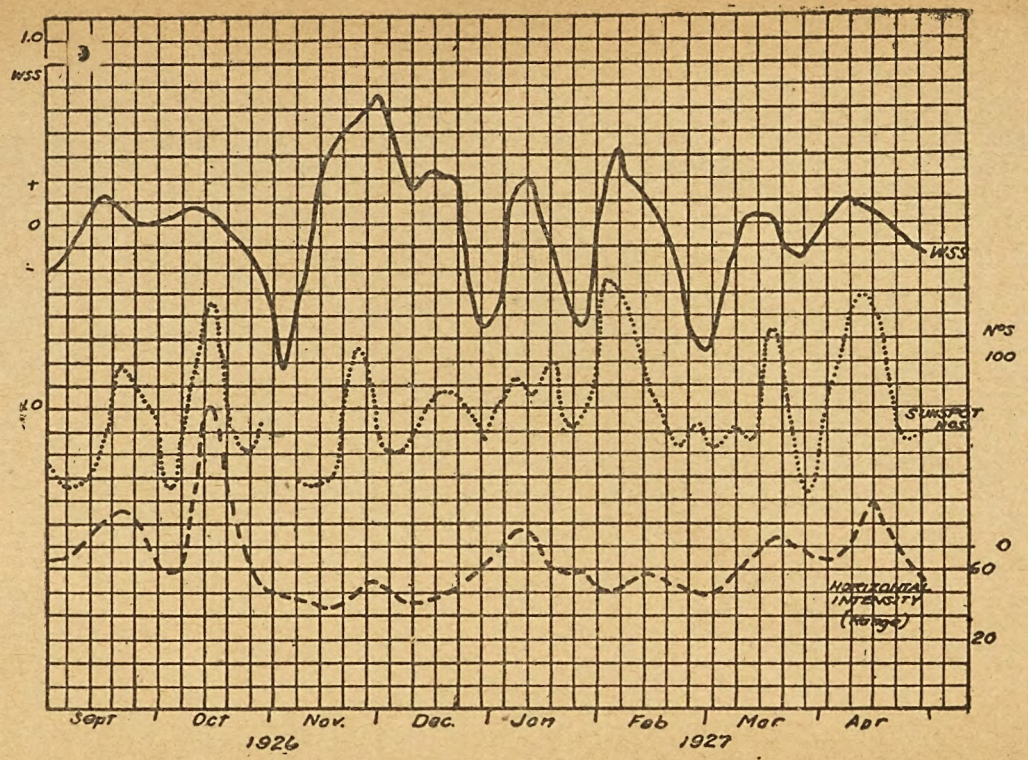

Fig. 3—Deviation of 5-Day Averages from Monthly Averages of Rocky Point (WSS), 10 A.M. and 3 P.M. and 5-Day Averages of Sunspot Numbers and Horizontal Intensity (Cheltenham), 1926–1927.

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As an example of five-day signal and sunspot averages over a period of good agreement, Fig. 3. is given. This shows the reception of the transatlantic Radio Corporation station WS (Rocky Point, L.I.), at a distance of 435 km. from Washington from September 1926 to April 1927 inclusive.

In addition to the signal and sunspot curves, a curve of the five-day average of the range of the horizontal intensity of the earth's field as observed at Cheltenham, Md., is included in Fig. 3. The resemblances between these curves are really striking, though we find here also the relative shifts in phase between the sunspot numbers and the signal intensity already mentioned. In some cases the signals evidently lead, while, in other cases, they lag.

Atmospheric Disturbances

The examination of the observational material of the Bureau of Standards on daylight disturbances between 9.000 m. and 20,000 m. wave length since 1918, has failed to show the definite connection with changes in solar activity shown by the long-wave signal strength observations. In the earlier measurements the strength of the atmospherics was determined by the shunt across the telephone at which three crashes could be heard in ten seconds. This method was subject to many inaccuracies including the effect of changing observers and possible changes in the sensitiveness of the telephones. The present method, adopted in 1924, rates the st ength of the disturbances in terms of the measured strength of an artificial signal which is just readable through them. On account of the earlier uncertainties, it is difficult to construct a complete curve of disturbance strength. It seems certain, however, that the daylight atmospherics at a wave length of 12,000 m. between 1920 and 1924 were considerably stronger than during 1918-1919 and during 1925 and 1926. This would indicate a general inverse correlation with the changes in the sunspot cycle. This relationship is roughly shown in Fig. 4.

Fig. 5. shows the deviations of the individual monthly averages from the 3-year monthly averages of the 20.000 m. daylight atmospheric disturbances and of sunspot numbers from 192 to 192 . The deviations are used rather than the monthly averages themselves in order to eliminate the large sesasonal variations of the atmospherics. The atmospheric disturbance curve is rather noncommittal but with some evidence of an inverse correlation with the sunspots. The indistinctness of this relationship may be compared with the much more definite correlation of sunspots and signal intensity as shown by the same method in Fig. 2.

Attempts to show short period correlations between daylight atmospherics and sunspots by means of 10-day averages and by 27-day periodic averages have been without result,

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although Pickard (2) has indicated a direct correlation in the case of night signals in the broadcasting range by means of 27-day averages.

In another place (7) I have shown how close a relation exists between atmospherics and some other natural pheno-

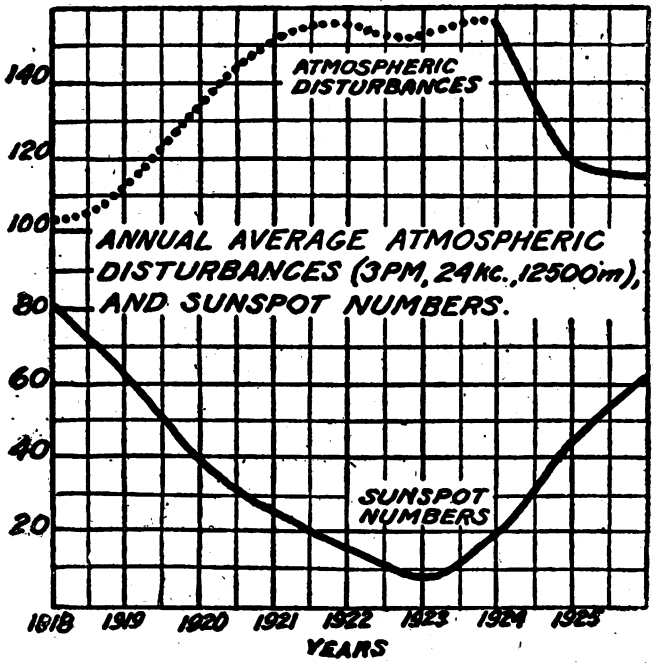

Fig. 4

mena such as temperature and thunderstorms, and since the weather changes are probably more or less dependent on solar activity it may be that the influence ot solar activity on the weather and that of the weather on atmospherics is the indirect path by which the connection between atmospherics and solar action must be traced.

Our present knowledge concerning the relation between solar activity and radio transmission may be briefly summarized as follows :

It seems practically certain that long wave daylight signal strength has increased since 1923, and there is fair evidence that the annual averages of signal intensity since 1915 have roughly followed the sunspot curve.

It is also reasonably certain that night transmission at medium and long wave lengths is often reduced at times of high sunspot numbers.

The information regarding the effects of the sun on long wave daylight transmission averaged in periods of a few days

(7) Proc. I.R.E. Vol. 15, p. 837, 1927.

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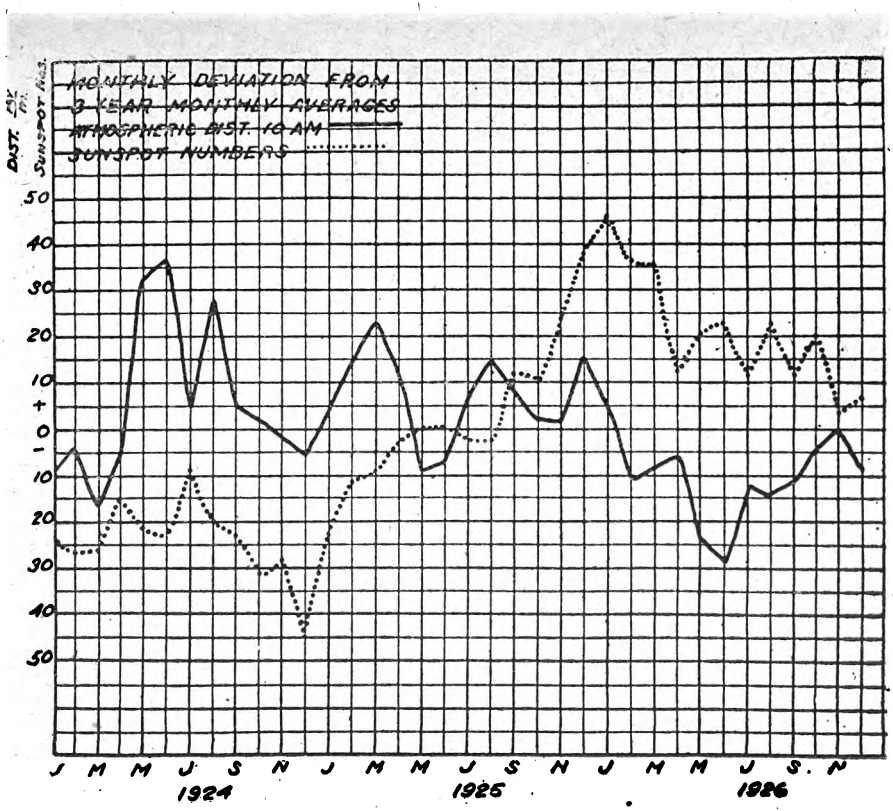
MONTHLY DEVIATION FROM
3 YEAR MONTHLY AVERAGES
ATMOSPHERIC DIST. IN A.M.
SUNSPOT NUMBERS
DIST. & SUNSPOT Nos.
50
40
30
20
10
+
0
-
10
20
30
40
50
J M M J S N J M M J S N J M M J S N
1924
1925
1926

Fig. 5

and ultra-short wave transmission in general, is still somewhat discordant.

There seems to be some evidence that the long wave daylight atmospheric disturbances have an inverse relation to sunspots when averaged over long periods.

While the sunspot numbers appear to give a rough indication of the solar condition affecting radio transmission, it seems probable that they are only an imperfect index of these conditions. It may be that we must distinguish between the solar influences on transmission depending on the general activity of the sun and those varying with its rotation.

April, 1928.

Appendix

The following is a brief summary of a communication on the above subject.

G. Breit, M. A. Tuve, and O. Dahl. Effective Heights of the Kennelly-Heaviside Layer in December 1927 *and January* 1928.

These heights have been measured at Washington D.C. by the echo-method, and the transmission used has been improved so as to obtain sharp peaks representing the signal and its echoes on the record (details of the method are described in a paper by M. A. Tuve and O. Dahl, to be published in the Proc. Inst. Radio. Engineers). Interference between the successive waves is completely eliminated and hence no correction for relative phases of interfering waves has to be made.

Cases of single, double and even triple echoes are found. When only single echoes were recorded, the usual effective height of the Kennelly-Heaviside Layer was approximately 140 miles : when double echoes were observed, the usual effective heights were 140 and 280 miles : in the case of triple echoes they correspond to 67, 140 and 280 miles. Such multiplicities had not been observed in the authors' previous tests. There were cases of multiple echoes, but the retardations were not different from each other by factors of two as now found.

The interpretation of the results, which may correspond to multiple reflection, is difficult. It is not clear why the height of 70 miles should have appeared in only a few cases, and why there is no effective height of 210 miles. The results at least seem to show that the phenomena due to the conducting layer are much more complicated than is often thought.

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PROGRESS IN THE STUDY OF THE GREEN AURORAL LINE λ 5577-350

by

Harold D. BABCOCK

The theory of Vegard (Phil. Mag. 46, 193, 1923) attempts to account for this line in the auroral spectrum by the bombardment of crystals of solid nitrogen by cathode rays from the sun. Working in the cryogenic laboratory at Leiden, he found evidence (Ann. der Phys. 79, 377, 1926) which he construed as favorable to his theory, since he was able to produce, at approximately λ 5577, a wide band in the spectrum.

Several recent papers, however, offer impressive arguments showing that the line is really due to oxygen. McLennan and his associates have found that pure oxygen gives a sharp line coinciding with the auroral line, and the intensity of this oxygen line is greatly increased by mixing helium, and especially argon, with the oxygen. With elaborate precautions, McLennan and McLeod (Proc. Roy. Soc. A., vol. 115, p. 515, 1927) determined the wave-length of the oxygen line and found almost perfect agreement with the position of the line measured in the spectrum of the night sky by Babcock (Astrophysical Journal, vol. 57, p. 59, 1923). Precise confirmation was given by Cario (Zs. für Phys., vol. 42, p. 15, 1927) who found the wave-length of the oxygen line in terms of neon standards to be 5577.348, which is the same as that of the auroral line within the errors of measurement. Keys also showed (Phys. Rev., vol. 29, p. 209, 1927) that the line can be produced strongly in a mixture of oxygen and argon, but disappears as the oxygen combines with the tungsten electrodes.

Furthermore, McLennan and McLeod showed that the oxygen line which they measured is only about 0.030A wide, corresponding to the character of the auroral line, and they urge this, along with the coincidence in position, as strong evidence in favor of oxygen. The situation in regard to the luminescence of solid nitrogen is well summarized by McLennan, Ireton and Thomson (Proc. Roy. Soc. A., vol. 116, p. 1, 1927).

Hopfield has pointed out (Phys. Rev. vol. 29, p. 923, 1927) that the difference in the wave numbers of two unclassified oxygen lines in the extreme ultra-violet is the same as the wave number of the auroral line. He suggests that the two

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ultra-violet lines arise from combinations of one term with two others and that the auroral line results from a combination of these two. McLennan, McLeod and McQuarrie showed (Proc. Roy. Soc., vol. 114, p. 1, 1927) that the line can be provided for in the scheme of spectral terms which has been worked out for the oxygen spectrum. Recently Franck has tentatively suggested (unpublished) that the line may be excited in our atmosphere only when three oxygen atoms collide, two of which combine to form a molecule, releasing sufficient energy to excite the third to produce the green line.

The consensus of opinion is that the line is to be ascribed to oxygen, and indeed, few spectral lines in cosmic sources are better identified.

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LE ROLE RESPECTIF DE LA TRÈS HAUTE & DE LA BASSE ATMOSPHÈRE DANS LA PROPAGATION DES ONDES RADIOELECTRIQUES

par

Robert BUREAU

La propagation des ondes courtes n'est pas seulement régie par les couches ionisées de la très haute atmosphère. La basse atmosphère, celle où dans une épaisseur d'environ dix kilomètres se déroulent les phénomènes météorologiques usuels, fait également sentir son influence sur ce phénomène. Des recherches récentes ont déjà montré l'action météorologique sur la propagation des ondes longues. Il fut montré, depuis, comment elle s'étendait aux ondes courtes.

Notre but n'est pas d'exposer et de discuter ici les résultats auxquels on a ainsi abouti.

Qu'il suffise de rappeler que l'influence météorologique se manifeste non seulement en affaiblissant ou en renforçant l'intensité de réception des signaux, mais également en contribuant à fausser les relevés radiogoniométriques et en provoquant, sur les ondes courtes, certaines de ces variations rapides susceptibles parfois de rendre des signaux totalement illisibles.

1° *Les conséquences de l'action simultanée de la très haute atmosphère et de la troposphère sur la propagation des ondes.* — Nous voudrions seulement faire ressortir quelques-unes des conséquences de cette action simultanée de l'atmosphère supérieure et de l'atmosphère inférieure sur la propagation des ondes électromagnétiques.

La première conséquence est une complicatin inévitable des recherches. Des expériences, nous ne pourrons tirer de conclusions qu'autant que nous serons parvenus à séparer l'action de la très haute et celle de la basse atmosphère. Le météorologiste, qui cherche à préciser l'effet des couches inférieures sur les anomalies de la propagation des ondes, devra ainsi s'attacher tout d'abord à connaître l'effet des très hautes couches. Et le physicien qui poursuit l'étude de l'action de ces hautes couches sur les ondes cherchera à préciser, autant que possible, et pour l'éliminer, l'action des couches basses.

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L'un et l'autre, le météorologiste comme le physicien, devront encore s'attacher à faire ce départ entre les causes dues aux deux domaines d'altitudes extrêmes, quand ils voudront tirer parti des lois qu'ils auront exprimées. Ce n'est qu'à ce prix qu'ils pourront utiliser les ondes radioélectriques comme un moyen de sondage : l'un afin d'avoir un mode supplémentaire d'exploration des masses d'air de la troposphère, en vue d'analyser leur structure et de préciser la nature et l'emplacement des surfaces de discontinuité qui les séparent; l'autre qui voudra, grâce aux ondes, suivre l'action ionisante du rayonnement solaire sur les couches raréfiées situées à des dizaines et des centaines de kilomètres d'altitude.

Mais cette complication des recherches n'est sans doute pas la seule, ni la plus importante conséquence de l'action simultanée des très hautes et des basses couches de l'atmosphère sur la propagation des ondes. Il est peu probable, en effet, que les modifications et les perturbations des couches basses soient sans liaison avec celles des couches très élevées. Sans dériver nécessairement les unes des autres d'une manière directe, elles peuvent, les unes et les autres, être influencées par une cause unique: le rayonnement solaire, Les recherches récentes montrent que le rayonnement solaire doit agir sur l'atmosphère basse, surtout par l'intermédiaire des centres d'action, mais avec un certain retard. Il agit certainement d'une manière plus rapide sur la très haute atmosphère et sur l'ionisation de celle-ci. Les variations de cette ionisation ont sur la propagation des ondes courtes une répercussion immédiate. Des observations systématiquement menées des phénomènes de propagation pourront donc, dans l'avenir, fournir de précieuses indications sur la prévision des centres d'action météorologiques, ce qui est l'un des problèmes nécessaires à résoudre pour parvenir aux prévisions à longue échéance.

Bien que rien ne prouve encore qu'il y ait des relations directes entre certaines perturbations de la très haute et de la basse atmosphère, de telles relations sont loin d'être invraisemblables : et certains phénomènes de la propagation paraissent être un indice sérieux en leur faveur. L.W. Austin a déjà signalé dans ce sens le parallélisme entre le renforcement anormal de certaines émissions et le passage de vagues de froid. D'un autre côté les recherches météorologiques de ces dernières années tendent déjà à reculer en altitude la limite des perturbations qui se répercutent sur les phénomènes météorologiques observables à la surface et à faire jouer un rôle de premier plan aux perturbations de la stratosphère.

Plus les études se précisent et plus il apparaît ainsi qu'aucune partie de l'atmosphère ne peut être considérée commc vivant d'une vie totalement indépenadnte et en quelque sorte en vase clos. De proche en proche on en viendra peut être à déceler une action de la très haute atmosphère sur la stratosphère et, par l'intermédiaire de celles-ci, sur la troposphère.

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Dans ce cas les ondes radioélectriques seront encore appelées à un rôle de premier plan dans les recherches, puisqu'elles nous donnent le meilleur des moyens d'exploration de la très haute atmosphère.

Tout ceci nous montre à la fois combien il faut être circonspect dans l'interprétation des résultats expérimentaux et quelle richesse de moyens nouveaux nous réserve l'étude de la propagation des ondes dans un domaine où elle ne paraît pas s'imposer à première vue : celui de l'influence du rayonnement solaire sur les mouvements et les aspects de la troposphère.

2° *Les anomalies de la propagation des ondes.* — Que savons-nous actuellement des influences respectives de la très haute et de la basse atmosphère sur la propagation des ondes courtes ? Quand on poursuit pendant de longues périodes des observations relatives à la propagation des ondes courtes, on constate l'influence générale de lois d'apparence régulière, qui forment comme un fond permanent auquel s'ajoutent des phénomènes accidentels souvent d'importance très considérable. Même si l'on élimine ces phénomènes accidentels, les lois régulières qu'on observe ne paraissent pas rigoureusement immuables. C'est ainsi, par exemple, que, au cours de l'hiver 1926-1927, les ondes de 25 à 30 mètres ont été beaucoup moins bien reçues dans la région parisienne qu'au cours des hivers précédents, tout comme si elles s'étaient alors comportées comme des ondes beaucoup plus courtes (R. Bureau, *Onde électrique*, 6e année, 1927, p. 52). Dans ce cas la cause perturbatrice s'est affirmée peu à peu, se renforçant régulièrement pendant près d'un mois pour diminuer et cesser de même, après avoir subsisté de longues semaines.

Ces anomalies ne paraissent pas affecter la forme générale des lois de propagation des ondes, mais seulement les coefficients des formules qui expriment ces lois.

Il est d'autres anomalies qui affectent la forme même des lois générales de propagation. Elles influencent particulièrement, sinon uniquement, les ondes de longueur d'onde inférieure à 40 ou 50 mètres. Tout se passe comme si l'action perturbatrice agissait en sens inverse de l'action normale. Alors que l'action normale fait apparaître les unes après les autres les ondes de plus de plus courtes au fur et à mesure que l'on avance du lever du soleil vers midi, l'action perturbatrice tendra à à produire le phénomène opposé : des ondes de 30 mètres apparaîtront avant des ondes de 48 mètres et des ondes de 20 mètres présenteront à midi une extinction là où celles de 30 mètres continueront à se propager librement. Tout ceci naturellement dans des conditions identiques de puissance, de distance, etc... et le même jour.

Quand ce phénomène se présente pendant de longues périodes au cours desquelles il va s'accentuant, on ne saurait

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l'attribuer au passage de perturbations météorologiques de la basse atmosphère. Il semble plus indiqué d'en rechercher la cause dans les propriétés physiques de la très haute atmosphère et en particulier de sa ionisation. C'est en suivant cette voie que nous avons été amené (C. R. t. 184, 1927, p. 1078) à admettre qu'il existait non point une seule couche ionisée agissant sur la propagation des ondes, mais deux couches (au moins) dont l'action combinée permet d'expliquer aisément les phénomènes relatés ci-dessus.

Enfin, la géographie exerce une influence profonde sur la propagation des ondes courtes, et tout se passe comme s'il existait à la surface du globe des séries de « zones conjuguées » entre lesquelles les liaisons par ondes courtes sont remarquablement aisées alors qu'entre d'autres zones elles sont anormalement pénibles.

En résumé, on peut classer de la manière suivante les phénomènes observées :

a) une loi générale régulière et relativement simple exprimant la portée en fonction de la longueur d'onde de l'heure de la saison : ceci pour une puissance donnée.

b) des variations progressives et apériodiques des coefficients de cette loi.

c) une loi perturbatrice déformant la première et provoquant sur les longueurs d'ondes les plus courtes une action opposée à la loi générale.

d) des variations accidentelles, irrégulières.

e) des influences géographiques.

a) et *b*) et *c*) sont très vraisemblablement dues à l'effet des couches ionisées, *d*) à l'influence de la basse atmosphère. Il est plus difficile actuellement d'attribuer l'effet géographique *e*) à une portion de l'atmosphère et dans ce cas à laquelle l'attribuer ? En effet, le mode d'action des phénomènes de la basse atmosphère sur la propagation reste encore quelque peu mystérieux. D'une part, les surfaces de discontinuité météorologique (fronts froids, fronts chauds, occlusions, surfaces de subsidyence) agissent comme si elle sprovoquaient la réfraction des ondes ou encore comme si une portion de l'énergie de celles-ci se propageait le long de ces surfaces comme de véritables ondes de surface. D'autre part, la structure en altitude des masses d'air paraît influencer les coefficients de la propagation. On pourrait donc supposer que la présence presque permanente de vigoureuses discontinuités météorologiques en certaines régions du globe entraîne des dissymétries géographiques dans la propagation des ondes. Mais on peut tout aussi bien supposer que par suite d'actions très diverses, et en particulier sous l'influence du magnétisme terrestre, la répartition des couches ionisées de la très haute atmosphère n'est nullement symétrique et *qu'il existe une géographie assez stable des hautes couches ionisées.* Enfin il est possible que haute et basse atmosphère

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contribuent toutes deux à l'existence des influences géographiques sur la propagation des ondes.

3e *Les recherches relatives à la propagation des ondes.* — Pour élucider l'ensemble de ces problèmes, l'application de méthodes synoptiques dans les recherches relatives à la propagation des ondes présente de très grands avantages. De même que dans les recherches météorologiques proprement dites, l'une des difficultés principales rencontrées ici est la grande variabilité des phénomènes d'un jour à l'autre. Le seul moyen de la surmonter consiste à procéder simultanément à des observations et à des mesures sur la plus grande étendue possible de territoire, et en plus, dans le cas qui nous concerne, le long de la gamme des longueurs d'onde. On parvient ainsi à établir l'image des phénomènes réels en un jour donné. Voici une manière d'y parvenir :

Des émissions sont assurées en nombre suffisant, le long du spectre des ondes aux différentes heures du jour, et *écoutées dans un réseau dense et étendu de stations.* Pratiquement il faut se limiter si l'on veut que les expériences soient réalisables. Les recherches ci-après rentrent dans le cadre général ci-dessus. Elles ont déjà été entreprises par la quatrième Commission du Comité Français de l'Union Radioscientifique Internationale (U.R.S.I.).

1° Influence de l'heure du jour sur un spectre de fréquence dans une vaste région. Réalisation : 24 heures d'émissions quasi simultanées de plusieurs émetteurs placés au même endroit et travaillant chacun sur une longueur d'onde différente (6 par exemple : 88 mètres, 60 mètres, 39 mètres, 30 mètres et 23 mètres). En fait chaque émetteur assurait périodiquement des émissions de dix minutes et jamais plus de deux longueurs d'ondes n'étaient transmises simultanément. Extension de la zone d'écoute : France et Maroc.

2° Influence du jour et de la saison. La même expérience fut renouvelée, tout au moins à certaines heures de la journée, à intervalles réguliers (mensuels par exemple) ou pendant plusieurs jours consécutifs. Ce dernier procédé est particulièrement susceptible de mettre en évidence l'action météorologique des basses couches.

3° Variation des coefficients de la loi permanente. Pendant des années les mêmes écoutes sont assurées aux mêmes heures par les mêmes récepteurs.

4e Influences géographiques. Des émetteurs mobiles (navires, avions) assurent des émissions systématiques au cours de voyages répétés à diverses saisons et pendant plusieurs années successives sur les mêmes itinéraires.

En général toutes ces expériences ne peuvent aboutir que si l'on parvient à y faire collaborer de nombreux expérimentateurs répartis d'une manière assez dense et assez étendue dans des réseaux de postes. Ceci proscrit pour une grande part recherche urement individuelle et exige des expérimentateurs

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une discipline suffisante pour se plier à des programmes rigides et pour participer à des recherches à très longue échéance et sans grand éclat. Pour diverses raisons, le plus grand nombre de ces expérimentateurs travaillera à titre purement bénévole. Ceux qui y consentent et qui restent fidèles pendant des mois et des années à une collaboration ingrate et obscure ont nécessairement un esprit scientifique auquel on ne saurait trop rendre hommage. Ceux qui, en France, nous ont déjà permis de mener à bien les expériences résumées ci-dessus et grâce auxquels nous continuons à les poursuivre trouveront ici l'expression de notre profonde et admirative gratitude.

Le champ des expériences doit souvent dépasser les limites d'un pays, et l'organisation des recherches rentre alors fatalement dans le cadre international. Il faut que des accords internationaux établissent ce cadre en choisissant parmi les multiples expériences possibles. On peut dire que deux méthodes principales de collaboration internationale se présentent alors : l'expérience peu étendue, mais indéfiniment répétée d'un bout de l'année à l'autre et d'année en année pendant au moins plusieurs cycles solaires. Elle consiste à mesurer par toute la terre, à des heures déterminées, le champ d'émissions bien choisies.

L'expérience complète, mais rare, renouvelée deux ou trois fois par an, mais où l'on accumule un très grand nombre d'observations en les combinant avec des observations aussi complètes que possible des autres branches de la physique du globe (comme par exemple les journées de sondage de l'atmosphère).

En principe, on écouterait pendant 24 heures de suite, par toute la terre, des ondes réparties le long du spectre de fréquence et émanant de divers points du globe. Nous avons proposé un plan complet de ce genre à l'assemblée générale de l'U.R.S.I. à Washington.

La première méthode permettra l'élimination à la longue des phénomènes accidentels et passagers. La seconde au contraire permettra de rechercher les causes et le mode d'apparition des anomalies accidentelles qui surviendront le jour de l'expérience.

L'étude de notre atmosphère jusqu'à ses confins extrêmes à l'aide des ondes radioélectriques parviendra ainsi peu à peu à se créer des méthodes et des disciplines. On commence à peine aujourd'hui à entrevoir les possibilités. Celles que nous avons signalées ne sont d'ailleurs pas les seules. Pour n'en citer qu'une autre : les mesures de l'altitude des couches ionisées nous donneront peut être une jour une méthode assez simple d'investigation rapide.

Toutes ces recherches où interviennent les ondes électromagnétiques sont d'autant plus séduisantes et riches d'avenir, qu'elles sont presque toujours pour nous un moyen de mettre en évidence l'action du rayonnement solaire sur l'atmosphère terrestre.

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THE SOLAR AND LUNAR DIURNAL MAGNETIC VARIATIONS

by

S. CHAPMAN

1. These variations have much light to throw on solar and atmospheric problems, and through them the first indication was gained (by Balfour Stewart) of the highly conducting region in the atmosphere. But though they have been studied for nearly a century, many points concerning them remain obscure and await further investigation. The literature is too extensive to catalogue here: many references are to be found in my papers (1,2) cited at the close of this report.

To save constant repetition of the long phrases "solar diurnal magnetic variation" and "lunar diurnal magnetic variation", the symbols S and L respectively will be employed instead.

2. By Gaussian analysis Schuster found that the magnetic fields responsible for S and L are principally of external origin, but that there is also an internal part, which can be reasonably explained as due to currents in an inner conducting core of the earth, induced by the varying field of external origin. The latter field is generally attributed (in my opinion rightly) to a primary system of electric currents flowing in the outer atmosphere; a recent theory by Ross Gunn (3), attributing the S-field to the diamagnetic effect of upper atmospheric ions spiralling about the earth's magnetic field, seems to me incapable of explaining L, and if L is due to overhead currents it does not seem possible to maintain that S cannot be explained in a similar way.

3. The outer current systems necessary to explain S and L are of simple character. Their type can be explained qualitatively as due to electromotive forces induced in the atmosphere by simple horizontal convective circulation of the air across the vertical component of the earth's permanent magnetic field. In the lunar case the type of circulation is quite definite; it is a semidiurnal tidal oscillation, known independently from analysis of records of barometric pressure. One cogent piece of

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(1) Phil. Trans., 218, p. 1, 1917; *ibid.*, 225, p. 49, 1925.
(2) Proc. Roy. Soc., London, A, 115, p. 242, 1927.
(3) Ross Gunn, Physical Review, July 1928.

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evidence in favour of this statement is that *L*, like the corresponding barometric variation, undergoes a large change of amplitude (nearly 40 per cent) as the moon passes from apogee to perigee ; this is in agreement with the change in the moon's tide-producing force.

Until recently it was thought that the convective circulation associated with *S* was likewise that indicated by the barometer, but it now seems possible that *S* depends on an independent circulation produced in the upper atmosphere (too high up to affect the barometer) by local heating (1).

4. On the basis of the above theory estimates can be made of the total conductivity of the atmospheric layer in which the *S* and *L* current systems flow. Independent estimates based on *S* and *L*, assuming that the circulations are those deducible from barometric observations, were in fair agreement. Until recent radio measures of the high degree of ionization in the upper atmosphere were available, these estimated conductivities seemed very high, but now they appear less difficult to accept. The total ionization required is still very great, however, and as there is no likely cause save the sun's ultraviolet radiation, importance was attached to an apparent disproof by W.F.G. Swann of the possibility of this radiation being sufficient to produce the necessary ionization. This difficulty has recently been largely removed ; two serious flaws in the disproof have been pointed out by the writer ( ), and P.O. Pedersen, in a more detailed treatment (3), likewise concludes that the sun's radiation is sufficient. Another difficulty, however, has recently emerged (3) : if the mean free paths of the ions are sufficiently great, the earth's magnetic field may practically nullify the electrical conductivity in the direction of an applied electromotive force normal to the magnetic field. The degree of importance to attach to this difficulty is bound up with controversial questions as to the state of the atmosphere at high levels, but in the writer's opinion there is hope that further investigation will confirm the possibility of the passage of the electric currents at levels where the density of the air is great enough for this difficulty not to arise.

It should be added that the estimates of the total conductivity on which these discussions have been based may be subject to some revision, probably a reduction by a not very large factor ; in the case of *S* this is for the reason mentioned at the end of § 3. In the case of *L* it is on account of new complexities in its character that have only recently been established (§ 6).

5. This uncertainty as to the exact value of the total

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(1) Journal Lond. Math. Soc., 2, p. 131, 1927.
(2) Quarterly Journal Roy. Meteorological Soc., 52, p. 225, 1926.
(3) P.O. Pedersen. The Propagation of Radio Waves, Copenhagen 1927 ;

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conductivity does not impair the valuable information afforded by S and L as to the relative distribution of the conductivity over the earth, or as to the changes in relative intensity that occur from time to time, affecting the earth as a whole. Outside the polar regions, the conductivity is found to be greatest over the part of the globe on which the sun's rays fall vertically, and it diminishes with increasing zenith distance of the sun, towards the twilight circle ; it is relatively small over the night hemisphere. This implies, of course, a considerable seasonal variation in the midday conductivity over stations in European latitudes.

This seasonal variation depends on the changing orientation of the earth with respect to the sun, and not on an intrinsic annual change in the sun's radiation. But S indicates also that there is a large intrinsic change in the average intensity of the sun's ultra-violet radiation, of the order of 50 per cent., or perhaps even 100 per cent, in the course of the sunspot cycle ; maximum radiation (corresponding to maximum atmospheric conductivity as indicated by maximum intensity of S) occurs at, or near to, sunspot maximum.

6. It would naturally be expected that L should show a variation of intensity in the course of the sunspot cycle parallel to that of S, but this is not observed ; there is a variation, but distinctly smaller than that shown by S. There is also another still more striking difference between L and S, which shows that their modes of production are not so similar as their many resemblances at first sight suggest. This second difference relates to the changes in L and S observed during times of magnetic disturbance.

Confining attention to the tropical and temperate regions, on magnetically quiet days S is of a definite type which may be distinguished by the symbol Sq (q=quiet). On other days the difference between S and Sq is of a type quite different from that of Sq ; it is convenient to denote this difference by Sd (corresponding to a diurnally varying magnetic field of a known distribution in intensity and direction). The intensity of Sd varies, without much change of type, over a wide range, from zero on quiet days, to a magnitude on days of magnetic storm, equalling or exceeding that of Sq. Throughout these variations Sq is nearly constant. On the other hand L varies in intensity, according to the degree of disturbance, in general parallelism with Sd, while its type remains approximately constant throughout, the same as on quiet days (1).

7. The cause of this difference between L and S is not yet clear, but the writer concludes that L, unlike Sq, is produced primarily in high latitudes, where magnetic disturbance (including Sd) has its primary origin ; in this region there are great and irregular variations in the relative intensity of atmospheric ionization and conductivity. The behaviour of L suggests that the ionization in auroral regions, apparently due to the impact

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of corpuscles from the sun, at times exceeds that produced by solar radiation in equatorial regions (4); but the interpretation of the magnetic data is not yet sufficiently clear to permit this conclusion to be regarded as established.

8. Besides the slow progressive change, throughout the sunspot cycle, in the average intensity of *Sq*, there are also irregular changes in the intensity of *Sq* from day to day. These changes, unaccompanied by any mark d alteration in the type of *Sq*, are observable on the quietest days, and show no apparent correlation with magnetic disturbance. They are most naturally attributed to irregular day-to-day changes in the intensity of the sun's ultra-violet radiation. Such changes have been directly observed by E. Pettit, and it is of importance to attempt a correlation of the changes in *Sq* and in the ultraviolet radiation. These changes in *Sq* have scarcely been systematically studied as yet. The writer and Mr. J.M. Stagg have recently undertaken such an investigation; (Proc. Roy-Soc. London, A. 123, 1929).

April, 1928.

Addendum. The explanation suggested in § 7 of the difference between S and L described in § 6 now seems not the simplest available. In Proc. Roy. Soc. London, A, 122 1929 (in the press) I have outlined a new theory which attributes S to "drift-currents" due to the joint action of the earth's gravitational, electrostatic and magnetic fields on the free charges in the high atmospheric region where the mean free paths are long so that they do not contribute much to the conductivity, This is the diamagnetic region of Ross Gunn's theory, but I have shown that the drift-currents have a much greater magnetic effect than the diamagnetism of the ions. If this region is ionized by ultra-violet light, while the conducting layer below, in which L is produced, is ionized by neutral solar corpuscles, travelling from the sun with the streams of ions and electrons that produce aurorae and magnetic storms, the connection between L and magnetic disturbance, and the absence of connection beween Sq and magnetic disturbance, are satisfactorily explained; there are several auxiliary lines of evidence, which I hope to publish shortly, in favor of this explanation.

Décember, 1928.

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RECENT WORK ON TERRESTRIAL MAGNETISM AND ELECTRICITY

by

C. CHREE

27-day Interval. A recent research with Mr. J. M. Stagg, using the international magnetic character figures since 1906, confirmed an earlier research, which made use of the earlier years' magnetic character figures and of the Kew absolute daily ranges. The 27-day interval was recognisable in every single year. It is as true of exceptionally quiet as of exceptionally disturbed conditions. Sometimes the phenomena suggest intermittence in disturbed conditions, as if the solar area responsible for a succession of magnetic storms were during certain presentations to the earth an exceptionally quiet area. Intervals multiples of 27-days were recognisable, but no recurrence interval shorter than 27 days. The 27-day interval was most prominent in years of few sunspots. No certain difference was detected in the length of the interval, the solar latitude of spots having no apparent influence. There seemed a decided tendency for magnetically disturbed conditions to follow very quiet conditions after some 6 days.

Wolf's formula $R = a + bS$. At various times during the last 30 years I have applied this to data from whole years, 4-month seasons and months, R representing now the range of the regular diurnal inequality, now the absolute daily range. In either case, when results are included from a number of years, the formula fits the facts fairly, but less well when R is the absolute daily range; b/a is greatest at Kew in the equinoctial months, and least in the summer months. In many individual months, with small or moderate values of S, the absolute range is much larger than the formula would suggest. Substantial magnetic disturbance, when no visible spot is or has been for several days on the sun, is not uncommon near sunspot minimum.

Lag. When we employ mean results from a number of years, there seems a decided tendency for the monthly maximum values of S to be *followed* a few days later by a maximum of magnetic disturbance, but a minority of years do not show the phenomena.

Aurora and magnetic disturbance. At the Antarctic stations Cape Evans and Cape Denison, there was a clear association of

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bright aurora with magnetic disturbance. But, whereas in Britain magnetic disturbance is greatest in the night hours, in the Antarctic it is greatest during the day. The times of maximum disturbance at Cape Evans and Cape Denison differed: thus magnetic disturbance has not a diurnal variation dependent only on Greenwich time.

11 *year period in atmospheric potential gradient.* Mean yearly values at Kew for years near 1900 suggested a slight rise of potential gradient with increase of *S*. Dr. L.A. Bauer deduced a similar, but much larger. connection at Tortosa, and to a minor extent at Eskdalemuir. The annual values at these two stations, and at Kew since 1923, have shown little, if any, tendency to increase with *S*.

Earth currents. The Tortosa publications and work by Dr. Stenquist, members of Dr. Bauer's staff, and myself, have shown a close relationship between earth currents and magnetic disturbances. The 27-day interval is developed to a similar extent in the two sets of phenomena.

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SUR LES RELATIONS ENTRE LE SOLEIL ET LA TERRE

par

H. DESLANDRES

Je puis reprendre en 1928 les termes mêmes de mon rapport de 1925. Il faut enregistrer d'une manière continue tous les éléments variables du Soleil et de la Terre, et ensuite les rapprocher le mieux possible.

1. Le rayonnement ondulatoire du Soleil, dont l'intensité est exprimée par ce qu'on appelle la constante solaire, offre, d'après les beaux travaux d'Abbot, de petites variations, plus ou moins accidentelles ; mais la mesure est difficile et sujette à de nombreuses causes d'erreur : les résultats d'Abbot n'ont pas été acceptés par tous. J'ai demandé au Congrès de Rome en 1922 et à Cambridge en 1925, que la mesure de cette constante soit organisée dans différents pays, et en premier lieu avec les appareils et les méthodes d'Abbot. La difficulté de la mesure et la forte dépense qui est nécessaire ont apporté de grands obstacles.

Par contre, les taches et facules du Soleil, très faciles à relever, offrent des variations très fortes, avec la période de de 11 ans 1/3.

Sur la terre, les éléments tels que la température et la pression moyennes dans une station, varient peut-être avec la période solaire ; mais ces variations sont très petites.

Par contre, les variations de la boussole et des aurores polaires suivent très nettement celles des taches, au moins dans l'ensemble. Les grosses taches, comme on sait, ne sont pas toujours accompagnées, à leur passage au méridien central du Soleil, d'une belle aurore et d'un orage magnétique sur la terre ; on ne sait pas encore distinguer les taches dites actives de celles qui ne le sont pas. L'incertitude où nous sommes tient peut-être à ce que l'étude du Soleil n'est pas continue ; aussi, depuis 35 ans, en accord avec d'autres astronomes, j'ai réclamé la continuité des observations solaires, réalisée par une entente internationale. En 1925, j'ai conseillé aux observateurs solaires d'avoir, comme à Meudon, à côté de l'appareil qui relève le Soleil, un magnétographe enregistreur dont le papier noircit sans développement. L'observateur a ainsi sous les yeux à la fois le Soleil et la boussole ; lorsqu'un orage magnétique apparaît, le personnel entier de l'observatoire à l'ordre de se porter à tous les appareils qui peuvent servir à l'observation du Soleil.

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Comme, d'autre part, le nombre des observatoires solaires augmente, l'application de ce programme donnera à la longue des résultats utiles. Ainsi, en 1926, sur six orages magnétiques accompagnés d'une aurore visible en France, on a, pour trois de ces orages, observé, un peu avant, une perturbation solaire importante : à savoir, le 24 janvier à Pasadena, le 22 février à Kodaikanal et le 13 octobre à Meudon. Pour plus de détails, voir une note fort intéressante de M. d'Azambuja, astronome à Meudon, note publiée en 1927, dans le *Bulletin de la Société Astronomique de France*, page 178. D'ailleurs, dans les trois cas cités ci-dessus, on n'a pas suivi le soleil d'une manière continue pendant la durée entière de l'orage et dans les heures qui l'ont précédé ; il me paraît difficile d'en tirer des conclusions fermes. Une observation absolument continue serait nécessaire : elle est difficile à organiser, à cause des interruptions dûes au mauvais temps et à la nuit. L'exposé succinct de ces cas concrets montre bien les améliorations qui sont à poursuivre.

2. La question s'éclaire un peu, si on examine avec soin les conditions dans lesquelles le soleil peut nous envoyer les gros essaims d'électrons qui, d'après les beaux travaux de Stoermer, sont la cause des aurores et des perturbations magnétiques. Les points ordinaires de la surface et des couches sous-jacentes, en raison de leur température très haute, émettent constamment des électrons et aussi des rayons ultraviolets et X, dont une partie arrive à la terre et donne naissance à la variation diurne de l'aiguille aimantée. Mais, lorsqu'il y a un orage magnétique, comme la température est à peu près la même, j'estime que des corps radio-actifs, seuls capables de produire l'effet constaté, doivent intervenir, et ces corps radio-actifs ne peuvent provenir que des couches profondes de l'astre. On a alors un véritable volcan, comparable aux volcans terrestres.

Ces volcans, intermittents comme ceux de notre terre, ont une distribution régulière malgré la complexité des apparences ; c'est un résultat curieux de la recherche. Leurs intervalles, mesurés en longitudes solaires, sont des multiples de 60°, 30° et 15° Les pointes successives d'un même orage sont considérées comme dûes à des particules de vitesses différentes, qui sont courbées d'un angle différent par le champ magnétique extérieur du soleil. On constate que les intervalles entre les pointes principales et que les vitesses correspondantes des particules sont à peu près les mêmes pour tous les orages ; on retrouve une propriété des corps radio-actifs, ce qui est une vérification. Tout se passe comme si les volcans étaient fixés à une couche profonde qui tourne comme un corps solide, et sont constitués par 24 déchirures de cette couche, uniformément réparties autour de l'axe de rotation. Cette division régulière est d'ailleurs celle des corps à symétrie circulaire, qui se refroidissent ou sont soumis à des pressions internes croissantes.

Ces émissions corpusculaires et radio-actives, variables avec la période solaire, apparaissent aussi comme la cause

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première de tous les phénomènes, taches et facules, taches doubles à polarités magnétiques opposées, protubérances et rayons coronaux, observés sur le soleil et ses dépendances. La période plus ou moins longue du corps radioactif et le signe des charges électriques émises (rayons A ou B) interviennent dans la formation et la vie des taches, et aussi pour les différents aspects du phénomène.

Finalement les points d'émission corpusculaire dans le soleil, sont, en commençant par les plus actifs :

(a) Les volcans fixes de la couche profonde quasi-solide;
(b) Les taches et facules de la surface, qui se déplacent par rapport à cette couche.
(c) Les points ordinaires de la surface.

L'hypothèse radioactive, suggérée par les faits, explique aisément tous les points singuliers du phénomène, observés sur le soleil et sur la terre. La lecteur désireux de plus amples détail devra recourir aux mémoires originaux (1).

La petite aigulle aimantée et ses variations sont le point de départ et la base de la recherche ; il convient de les étudier avec soin sur tous les points du globe et, en particulier, dans la zone peu accessible des aurores polaires. J'appuie fortement le vœu émis déjà pour la création d'observatoires spéciaux dans le voisinage des pôles magnétiques terrestres.

3. D'autre part, le rayonnement solaire paraît avoir une influence sur les propriétés radioactives des corps ou tout au moins de certains corps, l'effet étant variable suivant les jours. Un laboratoire spécial a été organisé à l'observatoire de Meudon, puis à l'observatoire de Paris, pour l'étude du phénomène.

L'oxyde d'uranium, exposé au soleil, devient plus radioactif; le plomb, d'abord inactif, devient actif. Les toitures anciennes de l'observatoire en plomb et en zinc ont été trouvées radioactives sur la face exposée au soleil, sauf que l'on puisse attribuer le fait aux dépôts radioactifs de l'atmosphère.

Les premiers résultats, publiés par Mlle Maracineanu, devront être vérifiés et complétés ; il faut examiner la question sous toutes ses faces, avant de poser des conclusions qui sont contraires aux idées régnantes.

Avril 1928.

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(1) Comptes-rendus : 182, 1926, pp. 733 et 1031 ; 183. 1926, pp. 105, 493 et 1313 ; 185, 1927, pp. 10 et 626. Voir aussi "Nature" Londres 30 octobre 1926 du 8 octobre 1927.

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MEASUREMENTS OF THE AMOUNT OF OZONE IN THE UPPER ATMOSPHERE

by

G.M.B. DOBSON

The observations which were begun at Oxford in the autumn of 1924 have been continued daily when the sun was visible, except during the winter months when the sun is too low for observations to be made. In addition, a number of spectrographs, similar to that originally used at Oxford for this work, have been built, and by the kindness of a number of meteorologists, observations have been made during 1926 and 1927 at Abisko (N. Sweden), Lindenberg (Berlin), Arosa (Switzerland), and Montezuma (Chile).

The method of observation is to take spectrograms of the extreme ultra-violet end of the solar spectrum, and to compare the intensity of two wave lengths, one of which is just outside the great ultra-violet absorption band of ozone, and the other just inside the band. After suitable calibration of the apparatus this ratio can be used to find the amount of ozone through which the light has passed.

After exposure at the observing stations the photographic plates were sent back to Oxford and there developed, measured, and the amount of ozone calculated. The working of the scheme has on the whole been very satisfactory, for which thanks are largely due to the trouble taken by those who kindly took the observations for us.

The average amount of ozone present agrees well with that found by Fabry and Buisson in their original experiments at Marseilles, being equivalent to about 3 mm. of pure ozone if it were supposed all concentrated in a layer of pure gas at standard temperature and pressure. The amount is, however, variable both with time and place.

In all but equatorial regions there seems to be an annual variation of the amount of ozone, having a maximum in spring and a minimum in autumn. Though the range at Chile is very small, the date of maximum seems to be six months different to that in the northern hemisphere, as might be expected. So far as can be seen from the observations available the range of the annual variation increases with increasing latitude. At Arosa the range is about 1.0 mm. and at Lerwick about 1.2 mm. Moreover, the type of variation seems to change, as at Abisko there was a much more rapid fall between April

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and June in 1927 than at other stations. (There were not enough observations in 1926). Indeed during the Autumn of 1927 the Abisko values were as low or lower than those at Arosa. At Chile the values are about 2.1 mm. in April and about 2.2 mm. in October. The amount of ozone probably increases with increasing latitude in spring, but in autumn it increases but little and the maximum may be in temperate regions. This will be much better known when the results of the observations which it is hoped to make in the immediate future are avialable.

As regards the diurnal variation of the amount of ozone it is difficult to say anything definite, as in obtaining the constants of the instrument we have to assume that the ozone is constant through the day. No evidence has, however, yet been found to indicate that this is not correct, and the values in the morning and evening agree well. The observations published by M. Chalonge of the amount of ozone at night—using moonlight— indicate that the amount is not less by night than by day, and may be rather more.

MM. Cabannes and Dufay and MM. Lambert, Dejardin and Chalonge have measured the height of the ozone layer by taking measurements of the amount of ozone near sunrise or sunset. When the sun is high, the path-length of the sunlight through the ozone layer depends only on the sun's zenith distance, but when the sun is low the height of the ozone layer and the radius of the earth must also be taken into account. Thus, if we assume that the amount of ozone is really constant, this gives a means of estimating its height. The above observers found a height of about 45 kms.

In conjunction with Dr. Gotz, we have recently made measurements of the height of the ozone layer at Arosa by the same method on a large number of days. The heights found there are rather lower than those found by the French observers, being about 35 kms. The accuracy of the measurements is necessarily very rough, but it appears that the average height of the ozone layer is greater when the amount of ozone is larger. This seems to be the case both for the changes associated with cyclones and anticyclones and also for the annual variation, the height being greater in Spring than in Autumn. These results, however, still need further verification, and the measurements are being continued. The absolute value of the height deduced is very sensitive to small changes in one of the constants of the instruments, which is difficult to determine accurately, and the difference between the mean height found at Arosa and that found by the French observers may be due to this cause. Also it must be remembered that it is assumed that there is no diurnal variation of the amount of ozone, and if this is not true the heights will be wrong.

There is found to be a very marked connection between

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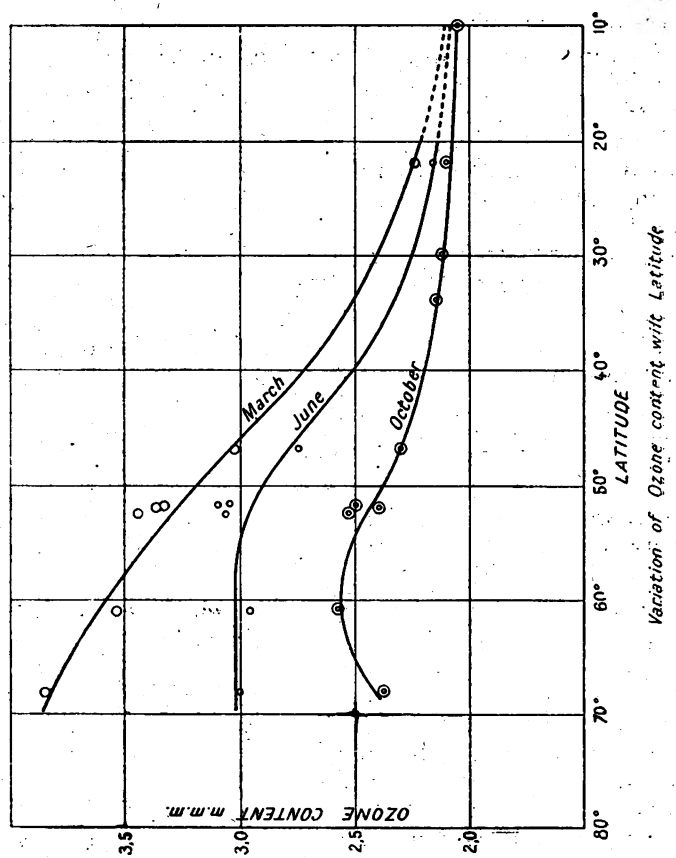

Variation of Ozone content with Latitude

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the amount of ozone and the general pressure conditions. The amount of ozone is low in anticyclones and high on the west side of cyclones. There is a very close connection between the temperature or pressure in the upper part of the troposphere and the amount of ozone. At present it is not possible to say with which characteristic the ozone is most closely connected, as the various upper air conditions are so closely connected amongst themselves. The correlation coefficients between the ozone and the various upper air quantities are as follows:

Pressure at 9 kms.	— 0.78
Mean temp. 4 to 8 kms.	— 0.67
Temperature at 14 kms.	+ 0.54
Pressure at 14 kms.	— 0.78
Height of tropopause	— 0.72

In Chile, where there are almost no weather changes, the amount of ozone is nearly constant from day to day, as might be expected.

If the ozone is really at 30 to 40 kms, it is very surprising that there should be so close a connection with the conditions lower down. At present there is no theory of the cause of the connection which seems to be entirely satisfactory. High ozone values are usually associated with polar winds in the troposphere, and low ozone values with equatorial winds, but again it is surprising that there should be this connection between such different levels, as the direction of the winds in the troposphere must often be very different to those in the upper stratosphere. The winds in the stratosphere are not sufficiently well known to say whether the ozone would be more closely connected with the origin of the air in the upper stratosphere than with that in the troposphere.

It has generally been supposed that the ozone present in the upper atmosphere was formed from oxygen under the influence of the sun's ultra violet radiation of wavelength about 1600 Å. The results of this investigation now make this seem very improbable. The highest ozone values are found in the Spring near the Poles, and the lowest values near the Equator. It would rather seem that some other agency formed the ozone and that the main influence of sunlight was to decompose it. It is, of course, known that the longer ultra-violet wavelengths decompose ozone into oxygen. The fact that the amount of ozone is a maximum at the Poles suggests that it is largely formed there and one would naturally assume that some action connected with the aurora was responsible for its formation. The visible aurora is, however, much too high, for it is seldom seen below 90 kms. There is a small, but apparently real, connection between the amount of terrestrial magnetic disturbance and the amount of ozone. This would also support the view that the formation was associated with the aurora.

Future Programme. Most of the spectrographs have now

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been recalled from the stations in Europe, and are now being recalibrated and will be sent shortly to the following places, where various meteorologists have kindly promised to take observations for us : Spitzbergen, Helwan (Egypt), Kodaikanal (S. India), Christchurch (New-Zealand), California and Winnipeg. The Australian Commonwealth Observatory at Canberra have also ordered an instrument and hope to take observations there. M. Buisson is also taking observations at Marseilles and Professor Cabannes at Montpellier. It is therefore hoped that in another 18 months we shall have a rough knowledge of the distribution of ozone over the world. It is not intended to continue this series of simultaneous observations when the present programme is complete, as the work is really too much for a private research, and if further observations are to be made it will probably have to be undertaken by a larger organisation.

April, 1928.

Note added Déc. 1928,

The following are the results so far obtained from the new stations.

	Aug. 1923	Sept. 1928
California.....	2.20 m/m	2.10 m/m
Helwan.....	—	2.13
Kodaikanal...	—	2.05
Christchurch.,	(2.85 to 3.90, very variable.)	

The ozone in New Zealand in August and September is higher and somewhat more variable than that for the same latitude in the Spring.

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TRAVAUX RÉCEMMENT FAITS EN FRANCE SUR L'ABSORPTION DES RADIATIONS PAR L'OZONE CONTENU DANS LA HAUTE ATMOSPHÈRE

par

Ch. FABRY

Cette question a fait, dans ces dernières années, d'importants progrès ; elle a été étudiée dans différents pays, et a été abordée de plusieurs points de vue. Je me propose de résumer ici les travaux faits en France depuis trois ou quatre ans ; les recherches faites dans d'autres pays et les travaux plus anciens ne seront cités que d'une manière occasionnelle.

I. Recherches de laboratoire sur l absorption par l'ozone. — Toutes les études sur l'ozone atmosphérique sont basées sur la connaissance des coefficients d'absorption de l'ozone, déterminés dans des expériences de laboratoire. Ce qui suit donne les désignations adoptées pour les diverses bandes d'absorption, avec les recherches récentes sur les coefficients d'absorption.

(a) *Grande bande de Hartley*, s'étendant de 2 200 à 3 200 environ, et responsable de la limitation du spectre solaire. Aucune mesure récente n'a été faite des coefficients d'absorption dans cette bande ; on se sert toujours des coefficients mesurés en 1912 par Buisson et Fabry, corrigés en partie par Dobson au moyen de ses observations sur l'absorption atmosphérique. De nouvelles mesures directes seraient utiles. Lorsque Fabry et Buisson ont fait leurs mesures, ils ne connaissaient pas les bandes de Huggins qui se prolongent dans une partie au moins de la grande bande de Hartley ; ils ont employé comme source de lumière une lampe à vapeur de mercure et les déterminations ont été faites seulement pour les raies du mercure ; une courbe d'absorption régulière a été tracée au moyen de ces nombres. Or les bandes de Huggins font que la courbe est beaucoup plus compliquée qu'on ne le supposait et les nombres doivent être en partie corrigés.

(b) *Bandes de Huggins*, dont l'attribution à l'ozone a été démontrée par Fowler et Strutt, s'étendant dans la région 3 000 à 3 400 environ. Des mesures ont été faites par M. et Mme Dutheil (2) : ils ont déterminé la position de tous les

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maxima et minima d'absorption (au nombre total de 47) entre 3050 et 3400, et ont mesuré toutes les valeurs correspondantes du coefficient d'absorption de l'ozone.

(c) *Bandes de Chappuis* dans le spectre visible, principalement dans le rouge et l'orangé. C'est à ces bandes que l'ozone doit sa couleur bleue sous une grande épaisseur et une forte concentration. Les coefficients d'absorption ont été déterminés, dans mon laboratoire, par M. Colange (1). Comme on le verra plus loin, la connaissance de ces coefficients a conduit MM. Cabannes et Dufay à des résultats importants.

(d) *Bandes infra-rouges.* — On connaît approximativement leur position, mais aucune valeur des coefficients d'absorption n'a été déterminée. Des mesures dans cette région seraient importantes.

II. Recherche des diverses bandes d'absorption de l'ozone dans le spectre de l'absorption atmosphérique. — Peu à peu, toutes les bandes d'absorption de l'ozone se trouvent identifiées dans l'absorption atmosphérique ; il se trouve même que, dans certains cas, l'absorption atmosphérique a donné des indications plus complètes que celles résultant des expériences directes.

(a) *Bande de Hartley.* — Elle continue à être principalement utilisée pour le dosage de l'ozone atmosphérique (*voir plus loin*).

Du côté des petites longueurs d'onde, cette bande s'étend jusque vers 2200 ; pour les longueurs d'onde inférieures à cette limite, l'ozone redevient transparent. Il est très probable que le soleil émet des radiations plus courtes. MM. Duclaux et Jeantet se sont demandés quel est l'absorbant qui nous empêche de recevoir ces radiations (6). Ils pensent que l'ammoniac, toujours présent dans la basse atmosphère, pourrait être responsable de cette absorption. Si cette explication est exacte, on pourrait espérer que, sur les hautes montagnes, un peu du rayonnement de la région 2000 pourrait parvenir. Une recherche dans ce sens a été faite par MM. Lambert, Dejardin et Chalonge, au sommet du Mont Blanc (3) (4) (16). Le résultat a été entièrement négatif. Il faut donc qu'un autre absorbant existe dans l'atmosphère. Il est possible que l'oxygène suffise à expliquer cette absorption. Des expériences sur l'absorption par l'oxygène ont été entreprises dans mon laboratoire par M. Chalonge ; elles sont encore dans la période de préparation et aucun résultat n'a été publié.

(b) *Bandes de Huggins.* — Ces bandes sont de mieux en mieux connues dans le spectre de l'absorption atmosphèrique. Cette absorption montre même, particulièrement dans la région 3500-3600, des bandes qui n'ont pas été mesurées dans les expériences de laboratoire et qui appartiennent probablement à l'ozone (5) (8).

Pour l'observation de ces bandes, MM. Cabannes et Dufay ont imaginé une méthode ingénieuse qui donne d'excellents résultats (8) (10). Au lieu de prendre la lumière qui vient direc-

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tement du soleil, ils étudient la lumière venant du ciel bleu en dirigeant l'appareil dispersif vers le zénith. Le ciel agit simplement comme « un diffuseur commode ». Lorsque le soleil est près de l'horizon, ce diffuseur reçoit de la lumière qui a traversé très obliquement la couche d'ozone, mais qui n'a pas été affaiblie par son trajet à travers la basse atmosphère. De plus, l'ultra-violet est plus fortement diffusé que les radiations visibles. Par cette méthode l'observation des bandes de Huggins est extrêmement facile.

(c) *Bandes de Chappuis.* — Bien que placées dans le spectre visible, ces bandes ne sont pas faciles à observer dans le spectre solaire, à cause de la petitesse du coefficient d'absorption (1) et du peu de contraste entre les maxima et les minima. Elles ont cependant été découvertes dans le spectre solaire par Cabannes (7) et étudiées par Cabannes et Dufay (9) (11) au moyen des mesures d'absorption atmosphérique faites depuis longtemps par Abbot et Fowle. Ces mesures, très précises, donnent le coefficient d'absorption de l'atmosphère pour toutes les radiations de la région infra-rouge, visible, et du commencement de l'ultra-violet ; la « diffusion moléculaire », qui produit la lumière bleue du ciel, est responsable de la plus grande partie de cette absorption. Cabannes a comparé les nombres de Abbot et Fowle avec l'absorption calculée pour la diffusion moléculaire. Dans la plus grande partie du spectre, la concordance est très bonne, mais dans le rouge, l'orangé et le jaune, l'extinction atmosphérique est supérieure à l'extinction moléculaire calculée. Il y a donc, dans cette région, une absorption en plus de la diffusion. En calculant cette absorption, on trouve que sa courbe coïncide exactement avec celle donnée par Colange (1) pour la courbe d'absorption de l'ozone. L'épaisseur d'ozone nécessaire pour expliquer l'absorption observée est d'un peu plus de 3 mm., nombre en bon accord avec le résultat des autres mesures.

Le maximum d'absorption dans la région des bandes de Chappuis a lieu pour 6100, et la valeur correspondante de l'absorption quand le soleil est au zénith est d'environ 4 pour cent.

(d) *Bandes infra-rouges.* — Aucune recherche récente n'a été faite. Il faut cependant rappeler que Fowle, en 1917, a publié d'importantes recherches sur la partie du spectre solaire correspondant aux grandes longueurs d'onde. Cette région contient de grandes bandes d'absorption dûes surtout à la vapeur d'eau ; cependant vers 10 μ existe une bande qui n'est pas attribuable à la vapeur d'eau, et qui est peut-être dûe à l'ozone. Comme on l'a indiqué plus haut, il serait très utile de faire des expériences de laboratoire pour la mesure des coefficients d'absorption de l'ozone dans la partie infra-rouge du spectre.

III. Mesure de l'altitude de la couche d'ozone. — Les dosages d'ozone de la basse atmosphère, jusqu'au sommet des plus hautes montagnes (analyse chimique et expériences

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d'absorption des radiations ultra-violettes artificielles) montrent que l'ozone n'y est pas en quantité suffisante pour expliquer l'absorption des radiations solaires. L'ozone doit donc exister surtout aux très grandes altitudes.

Buisson et Fabry ont suggéré que l'on pourrait mesurer l'altitude de la « couche d'ozone » en étudiant la loi de croissance de l'absorption lorsque le soleil s'approche de l'horizon. Ce programme a été réalisé par Cabannes et Dufay (8) (10) en appliquant leur méthode d'observation de la lumière venant du ciel au zénith. D'autres mesures ont été faites par Lambert, Déjardin et Chalonge (5) au sommet du Mont Blanc, en observant directement la lumière du soleil s'approchant de l'horizon. Ces diverses mesures s'accordent pour fixer une très grande altitude: autour de 45 à 50 km. Il ne fait d'ailleurs pas chercher une signification très précise dans ces nombres, mais seulement un ordre de grandeur car l'ozone n'est certainement pas limité à une couche mince.

Il serait intéressant d'acquérir des données plus complètes sur la petite quantité d'ozone qui peut exister dans la partie de l'atmosphère accessible à l'homme. Les analyses chimiques semblent très difficiles et incertaines. La méthode d'absorption (expérience de R.J. Strutt, 1918) pourrait donner facilement des valeurs certaines. Des expériences dans ce sens, faites en divers lieux et à diverses altitudes, seraient utiles.

IV. Variations de la quantité d'ozone. — Ces variations avaient été indiquées en 1921 par Fabry et Buisson, qui avaient mesuré la quantité d'ozone pendant quelques semaines et attiré l'attention sur l'importance de la question. Depuis quelques années, la question est régulièrement étudiée par Dobson et ses collaborateurs ; ces recherches feront l'objet d'un rapport spécial.

En France, Buisson et Jausseran ont fait une série de déterminations en août et septembre 1925 à Digne (altitude 600 mètres) (12). D'autre part, Buisson fait à Marseille (14), depuis le commencement de 1927, des déterminations quotidiennes toutes les fois que cela est possible ; ces mesures confirment les grandes variations trouvées par Dobson, et sont en accord excellent avec celles faites à Arosa (Suisse).

Toutes ces mesures sont faites en étudiant l'absorption de la radiation solaire ; elles sont par suite faites pendant le jour Il serait intéressant de pouvoir faire des déterminations pendant la nuit. C'est ce que Chalonge a réussi à faire en utilisant la lumière de la lune (13). Ses déterminations (non encore publiées) ne sont pas encore nombreuses ; elles tendent cependant à montrer que la quantité d'ozone est *plus grande* la nuit que le jour. Si ce résultat est définitivement confirmé, il faudra modifier les idées que l'on se faisait sur la théorie de la formation de l'ozone atmosphérique. Il faudra admettre qu'il existe une cause de production de l'ozone indépendante du rayonnement

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solaire et que ce rayonnement agit seulement comme destructeur par sa partie ultra-violette (probablement entre 2000 et 3000).

Enfin, Cabannes et Dufay ont montré (11) que l'on peut avoir des valeurs de la quantité d'ozone en utilisant les mesures faites par Abbot et Fowle sur l'absorption atmosphérique. Ils utilisent pour cela les bandes de Chappuis dans le sepctre visible (7) (9). Les mesures d'Abbot et Fowle ont été faites au Mont Wilson en 1908 à 1920 et à Calama (Chili) de 1918 à 1920. On peut ainsi retracer l'histoire de la couche d'ozone pendant une période assez longue et antérieure aux observations faites pour l'étudier. Au Mont Wilson, on retrouve la variation saisonnière découverte par Dobson : à Calama, station située sous les tropiques, cette variation est à peine sensible. De plus, il y a de fortes variations d'une année à l'autre.

V. Connexion avec d'autres phénomènes. — Il est naturel de chercher une relation entre les variations de la quantité d'ozone et les autres phénomènes, solaires ou météorologiques. Les travaux de Dobson ont conduit à de beaux résultats.

Les mesures de Buisson et Jausseran à Digne (12) n'ont montré aucune relation entre l'épaisseur d'ozone et la valeur locale de la pression-atmosphèrique.

Les calculs de Cabannes et Dufay au moyen des mesures au Mont Wilson montrent, comme on vient de l'indiquer, de grandes variations d'année en année ; il y a lieu de chercher une relation avec les variations de l'activité solaire. Le résultat est encore incertain (11) ; la question pourra être définitivement résolue que lorsqu'on aura des observations s'étendant sur plusieurs périodes solaires.

Mesny a cherché s'il existe une relation entre l'épaisseur d'ozone donnée par Dobson et la bonne ou mauvaise propagation des ondes hertziennes. Les premiers calculs (non terminés et non publiés) ne montrent pas une telle connexion.

Lévine (15) pense que ses propres théories météorologiques sont d'accord avec les relations découvertes par Dobson.

VI. Articles d'exposition et de vulgarisation. — Ces articles sont cités à la bibliographie sous les numéros (15) à (21).

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ETUDE DES RELATIONS ENTRE LES MANIFESTATIONS DE L'ACTIVITÉ SOLAIRE ET LA PROPAGATION DES ONDES RADIOTÉLÉGRAPHIQUES

par

G. FERRIÉ et R. JOUAUST

La présente note n'a pas pour but d'apporter une contribution nouvelle aux recherches entreprises pour déterminer les relations qui existent entre l'activité solaire et la propagation des ondes radiotélégraphiques. Nous voulons seulement exposer quelques considérations sur la manière dont à notre avis doit être conduite l'étude destinée à mettre nettement en évidence ces relations.

Soupçonnée depuis les débuts de la radiotélégraphie, l'action du soleil sur la propagation des ondes ne fait plus aujourd'hui aucun doute; les grandes différences de portée entre le jour et la nuit, constatées dans l'emploi des ondes courtes, constituent un critérium indéniable de cette action. Ce qui importe maintenant c'est de déterminer les lois régissant cette relation.

Cette connaissance peut être fort utile aux techniciens de la Radiotélégraphie. Elle leur indiquera peut être comment ils doivent établir leurs dispositifs d'émission pour obtenir les portées les plus considérables et comment ils doivent les modifier suivant les diverses circonstances. Elle sera en tout cas fort utile aux astrophysiciens. De même que les météorologistes (Bureau) ont trouvé dans l'observation des parasites atmosphériques un nouveau procédé de prévision de l'approche des grains, de même ceux qui s'occupent de la physique du globe trouveront dans l'observation de la propagation des ondes un nouveau moyen de suivre les variations de l'activité solaire.

L'influence solaire sur la propagation des ondes n'est probablement qu'un phénomène indirect. L'action du soleil sur notre globe se traduit en effet par de nombreux phénomènes : ionisation de la haute atmosphère, perturbations du magnétisme terrestre, variations du champ électrique de l'atmosphère, production d'ozone...

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Un des premiers points à éclaircir serait de déterminer quelle est celle de ces actions qui retentit sur la propagation des ondes.

Il est généralement admis aujourd'hui que c'est à l'ionisation de la haute atmosphère qu'il faut attribuer les phénomènes qui accompagnent la propagation des ondes. Presque tous les auteurs, reprenant une hypothèse émise il y a déjà longtemps et d'une façon indépendante par Kennelly, Heaviside et Nagaoka, admettent l'existence dans la haute atmosphère d'une couche fortement ionisée sur laquelle les ondes radiotélégraphiques viendraient se réfléchir ou dans laquelle elles se réfracteraient par un phénomène analogue à celui du mirage.

Mais nous ignorons tout de la constitution de cette couche. Pour ce qui est de sa composition chimique, de son degré d'ionisation, de la variation de cette ionisation en fonction de l'altitude, nous en sommes réduits aux hypothèses.

C'est ce qui explique que les diverses théories relatives à la propagation des ondes, quoique ayant un point de départ commun : l'existence de la couche ionisée, n'adoptent pas les mêmes idées pour la constitution de celle-ci et arrivent à des conclusions différentes.

A l'heure actuelle du reste aucune de ces théories ne cadre d'une façon satisfaisante, à notre avis, avec les résultats d'observation.

Certains auteurs (Nichols et Schelleng, Appleton, Breit) ont envisagé également l'action du champ magnétique terrestre sur la propagation des ondes. Cette action n'est pas encore bien prouvée et il semble que, si elle existe, elle ne devrait être considérée que comme une action perturbatrice venant modifier, sans l'altérer complètement, une loi générale de propagation.

C'est cette loi générale qu'il convient de dégager tout d'abord et il ne faut pas se dissimuler que c'est là une œuvre considérable. Nous voudrions insister dans cette courte note sur la façon dont nous pensons que doit être conduit le travail nécessaire à son achèvement.

L'étude des relations entre la propagation des ondes et les phénomènes solaires constitue un problème de géophysique et on ne peut songer à traiter ceux-ci comme on traite les problèmes de la physique ordinaire.

Le physicien travaillant dans son laboratoire peut produire à son gré les phénomènes qu'il veut étudier : il lui est loisible de faire varier les conditions expérimentales, il peut écarter toutes les causes perturbatrices. Il lui est donc possible de dégager en un temps court les lois régissant la marche du phénomène et cela par un travail uniquement personnel.

Il n'en est plus de même en géophysique ; c'est une science non d'expérimentation mais d'observations, et d'observations d'autant plus longues que d'une part les phénomènes à observer varient lentement et que d'autre part ils ont souvent leur appa-

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rence modifiée par des causes qu'il n'est pas permis à l'observateur d'éviter.

Tout travail se rapportant à la physique du globe, tout comme les travaux astronomiques, doit donc comporter des observations de plusieurs années et il est nécessaire de posséder une accumulation considérable de matériaux avant de chercher à les mettre en œuvre.

N'oublions pas, par exemple, que c'est pour avoir relevé journellement pendant plus de quarante ans le nombre des taches solaires que l'astronome allemand Schwabe put mettre en évidence leur période unidécennale.

Ce que nous venons de dire de la physique du globe et de l'astronomie doit s'appliquer aux relations entre la propagation des ondes et les phénomènes solaires. *A priori* on peut affirmer que, si cette relation existe, sa période doit être du même ordre de grandeur que celle des autres phénomènes caractéristiques de l'activité solaire, c'est à dire de l'ordre de onze ans.

De plus les causes perturbatrices ici sont très nombreuses, car l'action du soleil n'est pas seule à agir sur les portées réalisées en télégraphie sans fil. Par exemple, Austin a constaté, le premier d'une façon positive, une action des températures sur ces portées. Herath et Bureau ont cru voir une influence du front polaire sur la propagation des ondes et Bureau a ainsi expliqué les résultats d'Austin.

Ces phénomènes météorologiques qui ont une certaine durée sont évidemment susceptibles de masquer une action de l'activité solaire qui se produirait pendant le même laps de temps.

D'autre part les divers expérimentateurs qui ont commencé à étudier la question qui nous occupe ont généralement pris comme critérium de l'activité solaire le nombre de taches que l'on voit à la surface de l'astre. Or il semble bien qu'on doive admettre aujourd'hui (Maurain, Bauer) qu'il n'y a pas toujours concordance entre le nombre de taches et l'apparition sur notre globe de certains phénomènes comme les perturbations magnétiques. Il n'y aurait pas entre ces deux phénomènes une relation de cause à effet et on peut dire avec Bauer que la variation du nombre des taches n'est qu'une manifestation des variations de l'activité solaire dûe à une cause qui nous est encore inconnue et que cette manifestation peut faire défaut dans certain cas.

A défaut d'autre moyen de mettre en évidence ces variations d'activité solaire, nous sommes bien forcés d'avoir recours au nombre de taches, mais il devient nécessaire de faire porter les observations sur un temps assez long pour élimiter les circonstances où précisément ce procédé d'évaluation de l'activité solaire se trouve défaillant.

Pour pallier dans la mesure du possible aux causes perturbatrices dûes aux phénomènes de la troposphère, plusieurs des observateurs qui ont cherché à établir rapidement une relation

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entre l'activité solaire et la propagation des ondes, ont employé le procédé suivant : Se basant sur ce que la rotation moyenne du soleil est de 27 jours, admettant que l'activité solaire varie lentement et n'est localisée que sur une partie de la surface de l'astre, ils ont pensé que, pendant un temps d'une durée de quelques mois, les manifestations de l'activité solaire sur notre globe devaient présenter une périodicité de l'ordre de 27 jours.

Dans ces conditions, pour éliminer les influences météorologiques, on trace des courbes en prenant comme abscisse la phase par rapport à la période de rotation du soleil et comme ordonnée la moyenne d'un certain nombre d'observations faites à des époques de même phase pendant un certain nombre de rotations.

Au fond ce procédé revient à chercher à identifier deux courbes par l'identification de l'une de leurs harmoniques. Cette manière d'agir nous semble un peu critiquable.

Nous devons toutefois signaler que certains des résultats obtenus par ce procédé (Greenleaf Pickard) présentent une concordance assez remarquable entre les courbes caractéristiques du nombre de taches, celles de la propagation des ondes, et les nombres caractéristiques de l'état magnétique du jour. Nous devons mentionner toutefois que les vérifications tentées en France, d'après les résultats de mesures faites à l'Observatoire de Meudon, n'ont pas conduit à des constatations aussi satisfaisantes.

D'autre part certaines contradictions peuvent être relevées dans les résultats signalés plus haut. C'est ainsi qu'Austin et Pickard trouvent des relations de sens inverse pour l'action de l'activité solaire sur la propagation des ondes longues.

Il nous semble que dans ces conditions il convient, comme nous l'avons dit plus haut, de traiter le problème des relations entre l'activité solaire et la propagation des ondes en lui appliquant les procédés de travail qui ont si bien réussi pour l'étude de l'activité solaire avec Schwabe et Carrington, pour l'étude de la périodicité des variations magnétiques avec Lamont et Sabine, et plus récemment pour l'étude des relations du champ électrique avec Bauer.

Il conviendrait donc de faire des mesures et des observations sur tous les phénomènes qui peuvent être des indices des variations de l'intensité solaire (nombre de taches, variation des composantes du champ terrestre, état magnétique du jour, constante solaire, variation du champ électrique, variation de l'épaisseur de la couche d'ozone, facules, etc... Ces observations devraient porter sur un temps très long, qui devrait être au moins de l'ordre de onze ans. Ces études sont du reste déjà poursuivies dans bien des observatoires.

Il serait sans doute bon, dans la mesure du possible de les concentrer dans les mêmes observatoires, les mesures sur la propagation des ondes radiotélégraphiques étant effectuées

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aux mêmes lieux ou à proximité. Ces mesures seraient exécutées sur des ondes de diverses fréquences provenant de postes situés en divers azimuths par rapport au lieu d'observation, et seraient répétées plusieurs fois par jour, de façon à mettre en évidence et à permettre d'éliminer, s'il y a lieu, l'influence de l'heure du jour.

Il nous paraît nécessaire en outre que des observations, se rapportant à la fois aux phénomènes géophysiques et à la propagation des ondes, puissent être exécutées simultanément en plusieurs points qui ne seraient pas trop éloignés les uns des autres. En agissant ainsi on éliminerait certaines perturbations purement locales (1) et on pourrait au contraire mettre en évidence certaines actions localisées sur une portion étroite du globe.

Les observateurs chargés de ces mesures ne devraient avoir d'autre préoccupation que d'apporter le plus grand soin possible à leurs opérations, sans avoir à envisager la mise en œuvre de leurs résultats.

Plus tard, il serait possible, par un de ces procédés bien connus de tous ceux qui se sont occupés de physique du globe, de déterminer pour chacun des phénomènes observés les périodes des différentes courbes dont la superposition a pour résultante la courbe représentative des mesures effectuées. L'interprétation des résultats obtenus ne donnerait certes pas encore la solution complète du problème posé, mais fournirait de précieux jalons indiquant la voie dans laquelle il convient de la chercher.

Si, comme nous le pensons, les variations dans les phénomènes de propagation ne sont qu'une conséquence secondaire des variations de l'activité solaire, on pourra connaître le phénomène primaire qui les détermine par des considérations de phase ou de périodicité commune.

Le rôle de la phase nous paraît particulièrement important et nous rappellerons à ce sujet les conclusions tirées de la considération de cette grandeur par Bosler sur les relations entre les courants telluriques et les variations du magnétisme terrestre.

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(1) Dans un précédent rapport nous avons fait allusion à ces perturbations locales connues sous le nom d'évanouissement (fading). Il ne faut pas perdre de vue qu'elles ne constituent que des accidents dans la loi générale de la propagation et c'est pour cela qu'il convient de les éliminer dans les recherches ayant pour but la détermination de cette loi.

Le travail d'ensemble que nous proposons fournira du reste des renseignements précieux sur ces perturbations et il se peut que réciproquement l'explication de ces perturbations facilite l'interprétation des résultats généraux obtenus.

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ZUR OZON MANGEL DER TIEFEREN ATMOSPHÄRENSCHICHTEN

von

F.W. Paul GÖTZ

In Arosa (Graubünden) werden in 1860 m. Höhenlage seit 1921 laufende Messungen der Sonnenstrahlung durchgeführt, und zwar sowohl der Gesamtenergie, wie einzelner Spektralbereiche. Von ersterer mag bei dieser Gelegenheit der Höchstwert seit dem letzten ausführlichen Bericht (Das Strahlungsklima von Arosa, J. Springer, Berlin 1926) erwähnt sein : 1,63 g. cal / min. cm² am 18. März 1928, gemessen mit Silverdisk.

Die ultraviolette Strahlung wurde zunächst mit einer Cadmiumzelle gemessen. Dabei wurden mit Hilfe eines bei 3200 A° abschneidenden Glasfilters die längeren Wellen 3200 und das kurzwellige Ultraviolett 3200 A° gesondert erfasst. Aus der gegenseitigen Verschiedenheit des Gangs dieser beiden Bereiche vor Sonne wurden die Aenderungen des Ozongehalts der Gesamtatmosphäre für 1921 bis 1924 errechnet und ein Jahresgang von Frühjahr zum Herbst von etwa 4:3 gefunden.

Für die Verhältniszahlen des zerstreuten Himmelslichts zum Sonnenlicht ergab sich jedoch kein prinzipieller Unterschied, ob man nun nahe 3200 A° misst oder in kurzwelligen, schon wirksam dem Ozoneinfluss unterstehenden Bereich unterhalb 3200 A° : In den Luftschichten, in welchen durch Zerstreuung das diffuse Himmelslicht entsteht, kann keine wesentliche Ozonabsorption mehr vorhanden sein.

Auch im direckten Sonnenlicht verschwinden die prinzipiellen, ozonbedingten Unterschiede der beiden verschiedenen Ultraviolett-bereiche, falls man lediglich die Wirkung der unteren Atmosphärenschichten betrachtet. Die von Arosa aus unternommenen Intensitäts-messungen beider Ultravioletttbereiche in verschiedenster Höhenlage der Alpen können so direct auch als eine Wiederholung des bekannten Versuchs von Lord Rayleigh genommen werden, der nachts das Spektrum einer 6 km. entfernten Quarzlampe aufnahm ; anstelle dieser Quecksilberlampe trat hier die Sonnenstrahlung in — sagen wir — 3000 m Höhe, deren Aenderung untersucht wurde, nachdem sie auf etwa 600 m. Höhenlage herabgedrungen war.

Nachdem seit Sommer 1926 einer der hervorragend durchkonstruierten Dobson-Spektrographen in Arosa stationiert ist, musste dessen erhöhte Genauigkeit reizen, gelegentlich einige

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weitere derartige Daten beizubringen. So ist als gesamte atmosphärische Ozonschicht über dem 600 m hohen Chur und über Arosa (1860 m) gefunden: (O_3 in cm.):

	Chur	Arosa	Zwischenschicht
1926 Sept. 9	0.244	0.243	0.001
1927 April 26	0.308	0.300	0.008
— April 29	0.309	0.302	0.007
— Mai 3	0.322	0.322	0.000
— Mai 6	0.319	0.314	0.005
— Okt. 12	0.226	0.217	0.009
— Okt. 13	0.224	0.228	— 0.004
Mittel	0.279	0.275	0.004

Der scheinbare durchschnittliche Mehrbetrag von 0,004 cm in Chur erklärt sich zwanglos daraus, dass für die Berechnung lediglich molekulare Extinktion, nach Linke's Terminologie also ein Trübungsfaktor vom Wert 1 zugrunde gelegt ist; ein Trübungsfaktor 2, d.h. eine zusätzliche Trübung für die Zwischenschicht Chur-Arosa vom nochmaligen selben Effekt wie die Luftmoleküle selbst, würde die Differenz bereits überkompensieren (0.279—0.006 = 0.273). Es sei dem zunächst nicht näher nachgegangen, weil obige Messungen in Chur und in Arosa ja nicht streng simultan sind; es musste ja derselbe Spektrograph etwa am Morgen in Chur, am Nachmittag in Arosa Verwendung finden, ein Grund, der es auch nicht zuliess, grössere Höhenunterschiede nutzbar zu machen. Das Aroser Observatorium hofft nun bald im Besitz eines weiteren eigenen Spektrographen (vom Fabry-Buisson-Typ) zu sein; mit der notwendigen Möglichkeit simultaner Vergleichsmessungen wird sich dann auch die Unsicherheit, die in den Extinktionseinflüssen liegt, in aller Schärfe eliminieren lassen. Bei gleichmässiger Verteilung des Ozons in der Atmosphäre entfielen auf die Zwischenschicht Chur-Arosa 0.032 cm, auf Grund der chemischen Messungen könnten etwa noch 0.002 cm. O_3 erwartet werden.

Zusammenfassend war also optisch innerhalb der bisherigen Messgenauigkeit ein Ozongehalt der bodennahen Atmosphärenschichten nicht nachzuweisen.

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THE EFFECT OF OZONE ON THE TEMPERATURE OF THE UPPER ATMOSPHERE

by

E. H. GOWAN

Two methods of indirectly observing the temperature of the upper atmosphere have recently been developed. The first is due to Lindemann and Dobson, and makes use of a theory of meteors proposed by them. They obtain above 60 km. values of the temperature of the order of 300° K. Whipple has shown that some such temperature at that height will explain the refraction of sound waves giving rise to a zone of silence and an outer zone of audibility around a big explosion or a detonating meteor. As an explanation of this high temperature at such heights Lindemann and Dobson suggested the strong absorption of solar radiation in the ozone of the atmosphere. The average amount of ozone being known, also the approximate height of its centre of gravity, it seemed worth while to try to calculate the effect it would have on the temperature, assuming that the stratosphere as a whole is in radiative equilibrium.

The problem of the insolation of an atmosphere has been treated in a general way by Humphreys, Gold, Emden and Milne. Though some valuable conclusions can be drawn from the work of these authors, their results are a little difficult of application to the earth's atmosphere, where the absorption coefficients of important constituents vary so irregularly with the wave-length. Previous applications of their results to the stratosphere have assumed it isothermal, and have neglected ozone, which is the only gas besides water vapour whose absorption is important in the upper layers.

In radiative equilibrium the temperature of the air is determined by equating the amount of energy emitted to the amount absorbed. These amounts depend, of course, primarily upon the amounts of water vapour and ozone present; but the amount of water vapour depends upon the temperature. The only method of attack therefore is to assume a distribution of temperature, determine the proportion of water vapour at various heights, and on this basis calculate what the temperature would be. If one has assumed the right temperature curve, the

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final temperatures calculated will agree with the original assumptions. If the original assumptions were faulty, the calculated temperatures will differ from those assumed and one must assume a fresh distribution and start the process over again. In this way, by a series of approximations it is possible to arrive at a curve in which the temperatures initially assumed agree with those calculated.

Consider a layer of the stratosphere. Suppose it is at the same average temperature throughout, but in general different from the temperatures of the layers above and beneath it. The layer receives on its upper face radiation from the sun and from the higher layers of the atmosphere, and on its lower face radiation from the earth and the lower layers of the atmosphere as well as part of the sun's radiation which is reflected. One half of the total energy absorbed from these sources is radiated from each face of the layer.

Let K_λ be the coefficient of absorption for the layer at wavelength λ, adding together the separate absorptions of water vapour and ozone. Then the equation of radiative equilibrium is : $\int_0^\infty R_{\lambda T_0} d\lambda = \frac{1}{2} \int_0^\infty K_\lambda (S_\lambda + s_\lambda + E_\lambda + X_\lambda + Y_\lambda) d\lambda$

where $R_{\lambda T_0}$ is the radiation from the layer, equal to the energy of a black body at $T_0°K$, multiplied by the absorption coefficient K_λ.

S_λ is that portion of the sun's radiation reaching the layer ;

s_λ is that portion of the reflected solar radiation reaching the layer;

E_λ is that portion of the combined earth and troposphere radiation which reaches the layer.

X_λ and Y_λ are the radiations from the stratosphere above and below the layer respectively.

Radiations in every case are per unit area.

It is obvious that, owing to the irregular variation of the absorption coefficient K_λ, a graphical solution is the only one practicable.

It is also obvious that a large number of layers should be taken in carrying out the computation, but the number cannot be too great on account of the labour involved. Instead of expressing S , E_λ, etc., as functions of the optical height, it is more convenient, and quite in keeping with the principle of the system adopted, to decrease S_0 , E_0 , etc., the initial values of the radiations, by the amounts absorbed in the successive layers through which they pass.

It must be remarked that S_λ is actually a parallel radiation, while all the others are diffuse, and hence for them the layers should have a different (and larger) effective coefficient of absorption. It has been found, however, that if $E_{0\lambda}$, which

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is the most important of the diffuse radiations is assumed black at 260° K, the use throughout of the absorption coefficient for parallel rays introduces only a relatively small error.

For the purpose of the calculation, the stratosphere from 11 to 150 km, was divided into 9 layers, and an average tempeature T_0 assumed for each. Using this distribution of temperature, the amounts of water vapour and ozone in each layer were found. Whatever the source of the ozone in the atmosphere it is known to be produced in the upper layer. Therefore a distribution of it proportional to the oxygen from 45 km., the height of the centre of gravity of the layer, upwards, is a minimum in the upper layers, and hence gives a minimum tempeature there. Having settled the distribution of the water vapour and ozone, the required absorption coefficients were calculated from the data given by various investigators. Curves of absorption and radiation follow by means of a long system of calculating the successive decrements of the various radiations in the several layers. The totals of energy absorbed and radiated were found by plotting the curves to an appropriate scale and measuring the areas under them by means of the planimeter.

Three sets of approximations have been completed and the final ones are set forth in the accompanying table. The assumed temperatures T_0 are given first. Following them in brackets are the values obtained by calculation. The order of accuracy one can expect in the work at present is about five percent, and in every case the difference between the calculated and assumed values is less than this.

No ozone was used in computing the first row of temperatures, which was intended for use as a basis of comparison.

The second row was done with the ozone proportional to the oxygen above its centre of gravity, but below that trailing off rapidly to nil at 30 km.

The third row shows an attempt to keep the temperature from dropping again below 150 km. by suitably increasing the amount of ozone in the upper layers and decreasing that in the lower. The increase necessary between 100 and 150 km. was from 0.003 to 0.03 percent of the total thickness 0.30 cm. assumed, which gives an idea of the very small proportions necessary in the outer layers to produce a relatively large absorption of energy.

The important assumptions on which this work is based have been very carefully considered. Though changes in them are possible, on the whole they will not have any great effect on the results. The temperature of the lower layer calculated is known experimentally, and the discrepancy between the known and calculated temperatures is much less than the five percent allowed to the method in general. Also the general work done on the subject by the authors mentioned has established that a strictly isothermal region is not possible unless

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its optical thickness is zero. Otherwise the temperature falls gradually, and the characteristics of the case without ozone are seen to conform fairly well to this theory. It is felt that these considerations justify the opinion that the method in general is reliable, and that the results give an idea of the order of temperature to be expected. The agreement as regards both temperature and height with the indirect observations is, of course, reassuring, but it is hoped to go further and in greater detail into the problem in the near future.

km.	11–30	30–40	40–50	50–60	60–70
1	220 (224)	210 (213)	207 (209)	205 (204)	205 (204)
2	220 (224)	220 (222)	250 (256)	270 (268)	305 (304)
3	220 (225)	220 (220)	250 (255)	270 (271)	300 (292)

km.	80-100	100-130	138-150
1	205 (203)	← 205 (201) →	
2	290 (290)	240 (237)	220 (217)
3	300 (310)	← 300 (312) →	

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DISCUSSION OF THE GREENWICH SOLAR AND MAGNETIC DATA

by

W.M.H. GREAVES

Systematic solar observations were started at Greenwich in 1874 April and have been carried out ever since. Throughout the whole of the period covered by these observations the Greenwich magnetic records are also available, and so at the present time (1928) there are available for discussion over fifty years of solar and magnetic data. Such a discussion has been undertaken and a recent paper* gives the first results of an examination of the material up to the end of 1927.

For the purpose of carrying out the comparison two catalogues were prepared independently : one consisting of all spot groups of mean area 500 millionths of the Sun's hemisphere or greater, which may conveniently be called " naked-eye " groups, and the other of all magnetic disturbances with ranges equat to or greaterthan 30′ in declination, or 150 γ in Horizontal Force (or North Force for the years 1916-1925) or Vertical Force. A few groups whose mean area was rather less than 500 millionths, but whose maximum area was considerably more, were included in the catalogue of spots. The total number of spots catalogued was 455 and the total number of storms 405.

The communication in question represents an attempt to investigate to what extent individual storms bear a relation to individual spots. For this purpose a restricted list of storms was prepared, consisting of those whose ranges were equal to or greater than 1° in Declination or 300 γ in either of the other two elements. In a few cases in which a storm exceeded the prescribed limit in one element only, and that only by a small amount and by virtue of a single swing, it was not included in the restricted list. This list consists of 60 storms, the remaining smaller storms being held over for statistical treatment.

It was found on comparing these storms with the catalogue of 455 naked-eye spot groups that 36 out of the 60 commenced within four days of the central meridian passage of a naked-eye spot. The question is whether these 36 coincidences were purely due to chance or not. Now the average frequency

*W.M.H. Greaves et H.W. Newton. M.N., R.A.S. 88. 7. 556-567, May 1928.

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of naked-eye spot groups for the portion of the solar cycle during which the big storms occur is found to be about 1 spot group in 29 days, and consequently if there were no connection between storms and spots there would be an expectation of $8/29 \times 60$ or say 17 spots transiting the central meridian of the Sun within 4 days of the commencement of one of these 60 large storms. The actual number is 43 (some of the 36 storms just referred to having more than one naked-eye spot group transiting the central meridian within 4 days of the commencement). There is at any rate a suspicion of a real connection.

By restricting the storms still further it is found that the proportion of coincidences is increased. There are 17 storms known to have had ranges of 90′ or more in Declination, or 500 γ or more in either of the other elements; 15 of these 17 storms commenced within 4 days of the central meridian passage of a " naked-eye " spot group. The exceptions were the storms of 1892 August 12-13 with a range of 540 γ in Horizontal Force, and of 1894 November 13-14 with a range of 500 γ in Vertical Force. The first of these storms occurred in conjunction with a moderately sized spot, which however was seen, when near the limbs, to be associated with a large area of faculæ, a fact which in itself suggests that the spot had previously been a large one. It was actually the return of a large naked-eye spot which had itself occurred in conjunction with one of the 17 very large storms.

The storm of 1894 November 13-14 is of peculiar interest, because in spite of its intensity it occured at a time when there was no unusual activity visible on the solar disc, the activity indeed being far below the average for the year. Returning to the more general list of 60 large storms, 24 commenced at a time when there was no large spot group within 4 days of the Sun's central meridian. But in the cases of 7 of the 24 they commenced within 4 days of the central meridian passage of a limited region of the Sun which was characterised at one or both of the Sun's limbs by patches of faculæ of 1000 millionths of the hemisphere or more in area. If we accept large faculæ as criteria of unusual solar activity, we thus have 43 out of 60 storms taking place in conjunction with the transit of a pronounced disturbed area across the Sun's central meridian.

The discussion is naturally somewhat in the nature of an extension of the discussion by E. W. Maunder of 19 large storms which occurred in the period 1875 to 1903. But the conclusions to which it leads are by no means so definite as those reached by Maunder. The extension of the available material seems to have spoilt to some extent the definiteness of the earlier conclusions. On the whole, however, it does seem that individual storms and spots are associated with each other more often than can be ascribed to mere chance. Furthermore, the tendency to association seems to be greater for the very largest storms of all,

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It would appear that whatever solar activity is responsible for a magnetic storm, if it is sufficient to produce an unusually large storm, it will probably manifest itself as a large sunspot. But the storm of 1894 November 13-14 is a reminder that a large storm may originate from a solar disturbance which manifests itself as a small spot only, or possibly from something which does not manifest itself as a spot at all.

The paper also discusses the tendency of these large storms to be followed by a further disturbance one synodic rotation later. The somewhat disappointing conclusion was reached that such a tendency, if it exists, was but a small one. In ten cases out of the 60 the storm was followed approximately one rotation later by one of the 405 magnetic storms in the catalogue. Chance will account for some of these. It is worthy of notice, however, that in 5 out of these 10 cases, the second storm is itself one of the 60 large storms discussed. It is possible that a discussion of the smaller storms will yield more definite results as regards tendency to recurrence.

Other points discussed are : the time interval that elapses between the transit of a spot across the central meridian of the Sun and the commencement of any storm that may accompany it, and the tendency for the very largest spot groups to be accompanied by magnetic disturbance.

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THE DIAMAGNETIC LAYER IN THE EARTH'S ATMOSPHERE AND ITS RELATION TO THE DIURNAL VARIATION OF TERRESTRIAL MAGNETISM

by

ROSS GUNN*

ABSTRACT. A theoretical investigation of the motion of ions and electrons in the region of long free paths shows that the electrical conductivity in the direction of the earth's magnetic field is that predicted by simple theory. The conductivity in a direction at right angles to the magnetic field and in the direction of the applied electric field is zero, while the pseudo-conductivity at right angles to both is finite and the mechanism such that ions of both kinds are swept in the same direction. As a consequence of this, it appears that large circulating currents in the upper atmosphere of the type assumed in present theories (Stewart, Schuster, Chapman and others) of the diurnal terrestrial magnetic variations are hardly possible.

A new theory of the diurnal magnetic variation is worked out, which explains quantitatively the major phenomena in terms of the diamagnetic effect produced by ions spiralling about the earth's magnetic field. The diamagnetic intensity of magnetization of the upper atmosphere in the region of long free paths is found to depend only upon the total number of ions of all kinds per cubic centimeter, their mean kinetic energy, and the impressed magnetic field. The maximum calculated diurnal magnetic variation as a function of latitude was found to agree in form with observation. The average maximum number of ions of all kinds per cc. in the upper atmosphere was then computed from observed data and found to be approximately 10^{10}, a number not inconsistent with the ionic densities inferred from the data of wireless telegraphy.

Naval Research Laboratory. Washington, D.C.

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*Phys. Rev. Vol. 32, p. 133, July 1928.

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SUR LES PROPRIÉTÉS DIÉLECTRIQUES DES GAZ IONISÉS ET LA PROPAGATION DES ONDES ÉLECTROMAGNÉTIQUES AUTOUR DE LA TERRE

par

C. GUTTON et H. GUTTON

1. Sur les théories relatives aux propriétés diélectriques des gaz ionisés

Les théories de Eccles (Proc. Roy. Soc., London 1912) et de Larmor (Phil. Mag., 1924) font intervenir, pour expliquer la propagation lointaine des ondes courtes, les propriétés diélectriques des gaz ionisés.

Elles conduisent à montrer que, dans un champ alternatif, le courant de convection dû au mouvement des particules électrisées est en opposition avec le courant de déplacement et produit une diminution apparente de ce dernier. Il en résulte une diminution de la constante diélectrique ε du gaz :

$$\varepsilon - \varepsilon' = N \frac{4\pi e^2 c^2}{\omega^2 m}$$

ε' représentant la constante diélectrique apparente du gaz ionisé, c la vitesse de la lumière, e/m le rapport de la charge à la masse d'une particule, N le nombre de particules par cmc. et ω la pulsation des oscillations du champ.

Ces théories supposent que les actions mutuelles entre les particules électrisées peuvent être négligées. Or si cette hypothèse est suffisante pour les faibles ionisations et les fréquences élevées, il n'est pas certain qu'on puisse la conserver lorsque N est assez grand ou ω assez petit pour que la constante diélectrique ε' donnée par la formule précédente devienne négative.

On possède très peu de renseignements expérimentaux sur les propriétés diélectriques des gaz ionisés : il nous a donc paru intéressant d'étudier ces propriétés en vue de déterminer la limite d'application des théories relatives à la propagation des ondes radiotélégraphiques.

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2. Principe de la méthode expérimentale

Un résonateur à ondes très courtes (217 cm. ou 408,5 cm. de longueur d'onde) est constitué par deux lames de cuivre parallèles réunies par un fil de cuivre. Entre les lames est disposé un tube de verre de 3,8 cm. de diamètre contenant de l'hydrogène à basse pression. On peut ioniser ce gaz en y faisant passer des décharges. Une soudure thermo-électrique intercalée au milieu du fil du résonateur permet la mesure de l'intensité efficace du courant qui y est induit, lorsqu'on le dispose au voisinage d'un oscillateur dont on peut faire varier la période, entre les limites nécessaires, sans que change l'amplitude des oscillations.

Une ligne, sur laquelle on déplace un pont et dont les fils sont réunis à leur origine par une soudure thermoélectrique est également couplée à l'oscillateur et permet une mesure précise de la longueur d'onde de ses oscillations.

On trouvera la description de ces appareils dans l'*Onde Electrique* (t. 6, p. 137, 1927).

Les expériences ont été faites en utilisant des ondes très courtes afin que l'amplitude des oscillations électroniques reste toujours une très faible fraction du diamètre du tube contenant le gaz ionisé. Cette précaution est nécessaire, si l'on veut éviter une influence appréciable des parois du tube. La mesure du courant dans le résonateur donne l'ordre de grandeur du champ alternatif dans le gaz : il n'atteignait pas 16 v/cm. pour les ondes de 217 cm., et 20 v/cm. pour les ondes de 408,5 cm. L'amplitude des oscillations d'un électron libre n'est alors que. 0,05 cm. et 0.20 cm.

Ayant réglé la longueur d'onde de l'oscillateur de façon à obtenir le maximum d'intensité du courant dans le résonateur, nous mesurons, d'une part, cette intensité et, d'autre part, la longueur d'onde.

Nous faisons ces deux mesures d'abord lorsque le gaz contenu dans le tube n'est pas ionisé ; puis nous les répétons pour des ionisations croissantes du gaz, obtenues en augmentant l'intensité de la décharge dans le tube.

3. Résultats des expériences

Nous portons en abcisses les longueurs d'onde mesurées et en ordonnées le carré de l'intensité efficace du courant dans le résonateur. Nous obtenons, pour diverses pressions du gaz, les courbes représentées par la figure ci-jointe. Les flèches indiquent le sens dans lequel ces courbes sont parcourues lorsque l'ionisation augmente. Le point *A* correspond au gaz non ionisé.

On voit que lorsqu'on augmente l'ionisation, la longueur d'onde pour laquelle l'oscillateur induit un courant maximum

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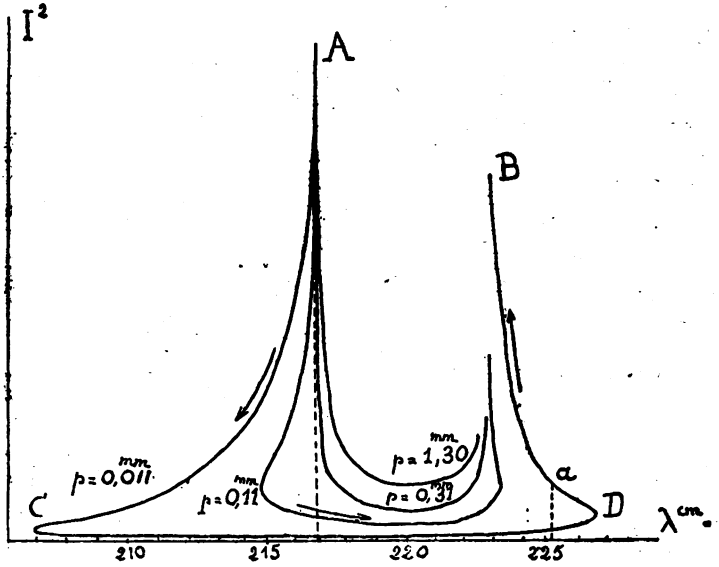
dans le résonateur diminue d'abord. Pour la pression 0.011 mm. de mercure, la longueur d'onde passe de 217 cm. à 207 cm (point *C* de la courbe). Ensuite, pour une très faible augmentation de l'ionisation, la longueur d'onde remonte à 227 cm. (point *D* de la courbe). Le courant de résonance est alors beaucoup diminué, ce qui montre que l'ionisation produit un fort amortissement du résonateur.

Enfin, pour les plus grandes ionisations la longueur d'onde diminue à nouveau jusqu'à 224 cm., l'amortissement du résonateur diminue aussi. La courbe tend vers un point B, qui correspondrait au cas où la conductibilité du gaz devient assez



grande pour que le champ électromagnétique ne pénètre plus dans l'intérieur et pour que le tube se comporte comme un conducteur parfait.

Si on augmente la pression, la diminution de la constante diélectrique devient plus petite et pour les pressions supérieures à 0,30 mm. on n'observe plus de diminution. Les courbes ont des formes analogues à celle que l'on obtient en remplissant le tube d'une solution très étendue de chlorure de potassium, dont on augmente peu à peu la concentration. Aux plus hautes pressions, le courant de résonance (et par suite l'amortissement) est plus faible dans les parties horizontales des courbes.

Des expériences sur un résonateur à onde plus longue (408 cm. 5) nous ont donné des courbes de même forme, avec toutefois les différences importantes suivantes : la diminution de la constante diélectrique disparaît pour une pression plus basse 0 mm. 10 et l'*ionisation, pour laquelle la constante diélectrique augmente rapidement entre les points* C *et* D, *est beaucoup plus faible.*

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4. Interprétation des résultats

Cherchons ce qu'indiquent, relativement à une variation de la constante diélectrique du gaz ionisé, les changements observés de la longueur d'onde.

Soit C la capacité du résonateur, L sa self-induction. Pour tenir compte des pertes d'énergie dans le gaz nous imaginerons en dérivation sur la capacité C une résistance r. L'oscillateur, fonctionnant à intensité constante, envoie à travers le résonateur un flux de force magnétique périodique de pulsation ω et d'amplitude Φ constante qui y induit une force électromotrice de la forme $e = \Phi\,\omega \sin \omega\, t$.

Appelons i l'intensité instantanée dans la self L. Un calcul facile montre que cette intensité est donnée par l'équation :

$$L\,\frac{d^2i}{dt^2} + \frac{L}{Cr}\,\frac{di}{dt} + \frac{i}{C} = \Phi\,\omega^2\left(\cos \omega\, t + \frac{1}{rC\omega}\sin \omega\, t\right)$$

ou

$$\frac{d^2i}{dt^2} + 2\,\alpha\,\frac{di}{dt} + \omega_0^2 i = \frac{\Phi\omega^2}{L}\left(\cos \omega\, t + \frac{2\alpha}{\omega}\sin \omega\, t\right)$$

en désignant par $\alpha = 1/2Cr$ l'amortissement et par $\omega_0 = 1/\sqrt{CL}$ la pulsation sans amortissement des oscillations libres du résonateur. Cette équation donne pour le carré de l'intensité efficace :

$$I^2 = \frac{\Phi^2}{2L^2}\,\frac{\omega^2(\omega^2 + 4\,\alpha^2)}{(\omega_0^2 - \omega^2)^2 + 4\,\alpha^2\omega^2}$$

Nous mesurons cette intensité pour la valeur de ω^2 qui la rend maximum. Cette valeur de ω^2 s'obtient en annulant la dérivée ; on trouve :

$$\omega^4 - \omega_0^2\,\omega^2 - 2\,\alpha^2\,\omega_0^2 = 0$$

d'où

$$\omega^2 = \omega_0^2\left(\frac{1}{2} + \sqrt{\frac{1}{4} + 2\,\frac{\alpha^2}{\omega_0^2}}\right)$$

que l'on peut écrire, puisque, comme nous le verrons, α^2/ω_0^2 est très petit :

$$\omega^2 = \omega_0^2\left(1 + 2\,\frac{\alpha^2}{\omega_0^2}\right)$$

λ_0 étant la longueur d'onde sans amortissement $2\pi c\sqrt{CL}$ la longueur d'onde que nous mesurons est donc :

$$\lambda = \lambda_0\,\frac{1}{\sqrt{1 + 2\,\frac{\alpha^2}{\omega_0^2}}} = \frac{2\pi c}{\sqrt{\frac{1}{CL} + \frac{1}{2C^2r^2}}}$$

Cette longueur d'onde est un peu plus courte que la longueur d'onde sans amortissement.

Pour nous rendre compte de la grandeur de cette différence,

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nous avons déterminé pour diverses ionisations du gaz la courbe de résonance du résonateur, afin de déterminer le rapport. $\frac{\alpha^2}{\omega_0^2}$. Nous l'avons toujours trouvé très petit vis-à-vis de l'unité : pour le point *a* de la figure, par exemple, il est inférieur à 0.0001; il en résulte que la longueur d'onde mesurée est très voisine de la longueur d'onde λ_0 et qu'elle ne s'en écarte que d'une quantité très petite vis-à-vis des variations de longueur d'onde que nous observons lorsque nous changeons l'ionisation du gaz. Les changements de longueur d'onde observés atteignent en effet 0,1. Nous sommes donc en droit d'admettre que les variations de longueur d'onde que nous observons indiquent un changement de valeur de la capacité du résonateur. Puisque la self-induction reste constante, les variations de capacité sont déterminées par des variations de la constante diélectrique. Les variations d'abcisses des courbes de la figure sont ainsi à très peu près proportionnelles aux variations de la constante diélectrique du gaz ionisé. Quant aux variations des ordonnées, elles représentent les changements d'intensité du courant de résonance et par suite renseignent sur les variations de l'amortissement du résonateur.

Les courbes de la figure relative aux pressions inférieures à 0 mm. 31, nous montrent que pour les plus faibles ionisations (région *A C* de la courbe) la constante diélectrique du gaz diminue. Puis, on atteint une ionisation pour laquelle la constante diélectrique augmente brusquement (région *C D* de la courbe) : pour les très fortes ionisations (région *D B* de la courbe), la constante diélectrique apparente et l'amortissement diminuent. Nous avons déjà indiqué que cette région correspondait à une conductibilité assez grande pour que le champ électro-magnétique ne pénètre plus complètement à l'intérieur du gaz.

La théorie de Eccles ne peut plus, lors des fortes ionisations, rendre compte des résultats de l'expérience, mais cette théorie établie en négligeant toute action mutuelle entre les particules électrisées, suppose par là même que l'ionisation est faible. Si le nombre d'ions par cmc. est assez grand pour que les actions mutuelles interviennent, ces dernières peuvent donner naissance à des forces élastiques, non négligeables vis-à-vis des forces électriques. Cette dernière hypothèse rend compte complètement de tous les résultats de nos expériences.

En effet, l'équation du mouvement d'une particule de masse *m* et de charge *e* dans un champ périodique d'amplitude F et de pulsation ω est, dans ces conditions :

$$m\frac{d^2x}{dt^2} + f\frac{dx}{dt} + Cx = Fe \sin \omega t$$

où *Cx* représente une force élastique et $f\frac{dx}{dt}$ l'analogue d'un frottement.

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Le courant de convection qui résulte de l'oscillation des ions en nombre N par cmc, s'obtient facilement à partir de cette équation et a la valeur :

$$N e \frac{dx}{dt} = \frac{N F \omega e^2}{(C - m\omega^2)^2 + f^2 \omega^2} \left[(C - m\omega^2) \cos \omega t + f \omega \sin \omega t \right]$$

La première composante est en opposition avec le courant de déplacement :

$$\frac{\varepsilon}{4\pi c^2} \frac{dF}{dt} = \frac{\varepsilon F \omega^2}{4\pi C^2} \cos t$$

lorsque C est inférieur à ω^2, c'est-à-dire lorsque l'ionisation est assez petite pour que les actions mutuelles entre les ions soient faibles. La constante diélectrique du gaz est alors diminuée.

Si l'ionisation est assez grande pour que C devienne supérieur à ω^2, la première composante du courant de convection est en phase avec le courant de déplacement et la constante diélectrique est augmentée.

Lorsque l'ionisation passe par la valeur pour laquelle C est égal à ω^2, il y a résonance entre la période propre des oscillations des ions sous la seule influence de leurs actions mutuelles et la période des oscillations du champ. L'amplitude des mouvements des ions est alors maximum. L'existence de cette résonance explique à la fois le fort amortissement du résonateur lors du passage à la résonance et le changement de sens de la variation de constante diélectrique. Celui-ci est dû à l'inversion de la différence de phase entre le champ et les oscillations des ions. La seconde composante du courant de convection est en phase avec la force électrique comme un courant de conduction.

Si la pression augmente, le terme $f\, dx/dt$ augmente aussi et l'amplitude des oscillations ioniques diminue. Les variations de la constante diélectrique sont alors plus faibles. Si, enfin, on diminue la fréquence des oscillations du champ, la quantité ω^2 devient plus petite et la résonance se produit pour de plus faibles valeurs des actions mutuelles c'est-à-dire pour des ionisations plus faibles. Ce résultat est encore d'accord avec celui que nous donne l'expérience.

5. Sur une objection de M. Pedersen relative a l'interprétation précédente

Dans le *Bulletin de la Société Danoise des Sciences* 1927, M. Pedersen a récemment publié une interprétation différente de nos expériences. Il ne fait pas intervenir les actions mutuelles entre les ions et conserve la théorie de Eccles même pour des ionisations très intenses. La constante diélectrique du gaz devient alors négative. M. Pedersen interprète ce résultat en admettant

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qu'un condensateur de capacité négative se comporterait sur un circuit oscillant comme une self. Il assimile le condensateur de notre résonateur à une capacité C_1 positive ou négative suivant que l'ionisation est faible ou forte. Il y ajoute une résistance r en dérivation pour tenir compte de la conductivité du gaz. Comme, dans nos expériences, le tube à gaz ne remplissait pas tout l'espace entre armatures, il suppose en série avec le condensateur C_1 un second condensateur C_2 de capacité invariable. Il en imagine enfin un troisième C en dérivation sur les deux premiers pour tenir compte du fait que des lignes de force peuvent aller d'une armature à l'autre de notre condensateur sans traverser le gaz.

Si on ajoute en série avec cet ensemble une self L, on a bien réalisé un schéma analogue à notre résonateur.

M. Pedersen cherche, pour des valeurs positives et négatives de la capacité C_1, l'impédance imaginaire du résonateur et en déduit la période pour laquelle le courant a le maximum d'amplitude en annulant la partie imaginaire de cette impédance. Il montre que la longueur d'onde correspondante et l'intensité du courant de résonance doivent varier suivant une loi analogue à celle que nous donne l'expérience. Ceci parce que la longueur d'onde qui, d'après son calcul, serait celle de la résonance, dépend un peu de la résistance r.

Pour plusieurs raisons cette explication ne peut être exacte.

Tout d'abord les longueurs d'onde calculées par M. Pedersen ne sont pas celles que nous mesurons.

Lorsqu'on annule la partie imaginaire de l'impédance d'un circuit, on trouve la période de résonance que l'on observe dans les conditions suivantes. La force électromotrice conserve une amplitude et une pulsation constantes et on fait varier la période d'oscillation du circuit. Or nous n'avons pas opéré de cette façon. Pour trouver la période qui correspond au maximum de courant dans le résonateur, nous laissons celui-ci invariable et nous modifions la fréquence de l'oscillateur, tout en maintenant constante l'amplitude de ses oscillations. Le flux de force magnétique envoyé à travers le résonateur conserve alors une amplitude constante Φ et induit une force électromotrice de la forme :

$$e = \Phi\omega \sin \omega t$$

dont l'amplitude est proportionnelle à la pulsation variable ω.

Nous avons fait plus haut, pour le cas d'un résonateur constitué par une self L, un condensateur C et une résistance r en dérivation sur le condensateur, le calcul de la longueur d'onde pour laquelle le courant dans le résonateur a l'intensité maximum et nous avons trouvé :

$$\lambda = \frac{2\pi c}{\sqrt{\frac{1}{CL} - \frac{1}{2C^2r^2}}}$$

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Le calcul de M. Pedersen pour le même résonateur donne (p. 93 du mémoire de M. Pedersen) :

$$\lambda = \frac{2\pi c}{\sqrt{\frac{1}{CL} - \frac{1}{C^2 r^2}}}$$

Donc, tandis que la longueur d'onde mesurée par nous est un peu plus petite que $2\pi\sqrt{CL}$ celle que calcule M. Pedersen et qu'il admet être celle que nous mesurons est un peu plus grande.

Comme tous les raisonnements de M. Pedersen dérivent du sens de cette différence, il est impossible qu'ils puissent expliquer nos expériences.

Nous avons montré d'autre part que la détermination des courbes de résonance nous avait permis de trouver la grandeur du terme $1/C^2r^2$ et de vérifier qu'il était tout à fait négligeable vis-à-vis de $1/CL$.

Il est, d'ailleurs, bien connu que l'amortissement a une très faible influence sur la valeur de la période d'oscillation, sauf au cas où cet amortissement devient si grand qu'il n'est plus possible d'observer nettement les phénomènes de résonance.

Le calcul de M. Pedersen n'est donc pas applicable à nos mesures : il fait intervenir des différences de fréquence qui sont en sens inverse de leur sens réel. Nous avons d'ailleurs montré, en outre, que ces différences sont si faibles qu'elles ne peuvent expliquer les résultats de nos expériences. Enfin nous avons fait des expériences en mettant à l'intérieur du tube à gaz la capacité du résonateur et en utilisant, afin que l'amortissement ne soit pas trop grand, de très faibles capacités. Nous avons encore trouvé que lorsqu'on augmentait l'ionisation, la longueur d'onde pour laquelle le courant était maximum, diminuait d'abord, puis augmentait brusquement après avoir passé par une valeur minimum. Il suffit de se reporter au mémoire de M. Pedersen pour constater que ses calculs ne peuvent plus interpréter cette observation.

L'existence d'une période propre d'oscillation des ions explique, au contraire, très complètement et très facilement tous les résultats des expériences.

Nous ajouterons que des recherches expérimentales sur la décharge à haute fréquence dans les gaz (Comptes rendus de l'Académie des Sciences, t. 186, p. 303 : 1928), nous ont aussi conduit, par des moyens bien différents, à l'idée d'une période d'oscillation des ions.

6. Sur la propagation des ondes électromagnétiques autour de la Terre

En tenant compte du fait, observé par nous, que la période des oscillations ioniques est d'autant plus longue que l'ionisation

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est plus faible, on arrive à des conclusions relatives à la propagation des ondes radiotélégraphiques autour de la Terre.

Nos expériences ont été faites sur des ondes très courtes, car des expériences sur des ondes longues nécessiteraient, pour éliminer l'influence des parois des tubes à gaz ionisé, des diamètres de tubes hors de proportion avec ceux qu'il est possible d'employer.

Les ionisations pour lesquelles on constaterait des résonances sur des ondes longues seraient beaucoup plus petites que celles sur laquelle nous avons expérimenté et pourraient être atteintes dans la parties basses de la couche d'Heaviside.

Voici alors quelle serait l'influence d'une période propre d'oscillation des ions.

Lorsque des ondes de fréquence plus grande que cette période se propagent dans la haute atmosphère, le courant de convection dû au mouvement des ions a, comme nous l'avons montré, une composante en opposition avec le courant de déplacement et produit une diminution apparente de la constante diélectrique. Comme le prévoient les théories de Eccles et de Larmor, des réflexions et des mirages renvoient les ondes vers le sol et assurent les liaisons lointaines de postes à ondes courtes.

Pour des ondes plus longues, la résonance entre les oscillations du champ et les oscillations des ions est atteinte. Le courant de convection est en quatrature avec le courant de déplacement et ne modifie plus la constante diélectrique du gaz. Mais l'amplitude des oscillations des ions devient beaucoup plus grande et il en résulte, à cause des chocs avec les molécules du gaz, une forte absorption d'énergie.

Des ondes plus longues encore ont une fréquence inférieure à la fréquence de résonance. Une composante du courant de convection est alors en phase avec le courant de déplacement et détermine une augmentation apparente de la constante diélectrique. Des phénomènes de mirage ne sont plus possibles, mais pour ces ondes longues la conductivité de l'eau de mer et du sol peut assurer la propagation dans des conditions qui sont celles de la formule d'Austin; la couche ionisée agit également pour favoriser par sa conductibilité cette propagation.

De part et d'autre de la longueur d'onde qui correspond à une résonance dans le gaz ionisé, les phénomènes qui interviennent pour assurer la propagation lointaine des signaux radiotélégraphiques sont ainsi très différentes.

Pour les fréquences voisines de la résonance, la transmission est mal assurée par la haute atmosphère qui absorbe ces ondes. Celles-ci sont d'autre part trop courtes pour que la propagation à la surface du sol se fasse sans affaiblissement exagéré. On s'explique ainsi, sans faire intervenir le magnétisme terrestre, le fait souvent constaté, que les longueurs d'onde au voisinage de 200 mètres sont peu favorables aux liaisons sans fil.

La réception des signaux sur ces longueurs d'onde est

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irrégulière et sujette à d'importants évanouissements. Au voisinage de la résonance, en effet, de faibles changements d'ionisation provoquent de très grandes variations de la constante diélectrique apparente et par suite de fréquents changements dans les conditions de propagation.

Les idées que nous venons d'exposer conservent les théories admises pour les ondes courtes ou pour les ondes très longues, mais elles peuvent contribuer à expliquer, d'une façon différente, les phénomènes irréguliers que l'on observe lorsqu'on établit des liaisons sur des ondes de quelques centaines de mètres ; mais nous pensons que si, outre une explication, on cherche des résultats numériques, il faut faire intervenir dans les théories de propagation les actions mutuelles entre les ions. Ces actions mutuelles ne peuvent être négligées, surtout si les ondes sont assez longues pour que des phénomènes de résonance se produisent.

Mai 1928.

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IONISATION IN THE UPPER ATMOSPHERE OF THE EARTH

E. O. HULBURT

ABSTRACT. A theory of the ionization of the upper atmosphere of the earth by the ultraviolet light of the sun is developed, based on known laws of pressures and constitution of the high atmosphere, ionic recombination, attachment of free electrons to neutral molécules, and diffusion of ions. It is concluded that the solar ultra-violet light is a necessary and sufficient cause of the Kennelly-Heaviside layer, and that hypotheses of other agencies of ionization, such as charged particles from the sun, penetrating radiation, etc., are uncalled for, except perhaps in unusual cases. Assuming the solar ultraviolet energy to be that of a black body at 6000° K and using known, or estimated, absorption coefficients of the atmospheric gases for ultraviolet waves below λ 1300 A, which cause photoelectric ionization, the electron curve for the sun overhead, i.e. for high noon in summer in the temperate zone, has a maximum of 3×10^5 electrons per cc. at a height of 190 km.

Below this, the ionization can not be calculated exactly, because of the lack of many facts which future laboratory experiments may supply, but a density of 10^4 to 10^5 electrons per cc., or 10^9 to 10^{10} ions per cc. (or a suitable mixture of ions and electrons) seems possible down to, say, 100 km. This ionization is shown to explain quantitatively many facts of wireless telegraphy, i.e. the skip distances, overhead absorption coefficients, limiting waves, ranges and the apparent heights reached by the waves. Taking into account the seasonal changes in the upper atmospheric pressures and the altitude of the sun, the electron layer for winter noon is found to have a maximum of 1.42×10^5 at a height 147 km., and the ionization below this is less than the summer values by a factor of 2 or so. After sunset the maximum ionization is found to decrease by a factor of about 5 in the small hours of the morning; below the maximum the decrease is greater. These seasonal and diurnal changes in the ionization are shown to be in agreement with the corresponding variations in wireless wave propagation phenomena.

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The potential energy of the daytime ionization in a 1 cm². column of the atmosphere is found to be at least 1 erg and the assumption that less than 1% of this is liberated as light will account for the light of the night sky, or the " nonpolar aurora " as Rayleigh calls it. Due to diffusion of the ions along the magnetic force, the upper ionic spray of the ionized layer diffuses to the magnetic poles, concentrates there and causes the aurora. Calculation indicates that the ozone of the atmosphere is perhaps not directly connected with the foregoing ionization, but is formed by longer wavelengths of ultraviolet light from 1300 to 1800 A. *

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* Phys. Rev. 31, p. 101, 1928.

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OF THE ORIGIN OF THE AURORA BOREALIS

by

E.O. HULBURT*

ABSTRACT. It has been assumed by Birkeland, Störmer, Vegard and others that the aurora is caused by charged particles from the sun, which are diverted to the polar regions by the magnetic field of the earth. There are possible objections to this, namely: if the charged particles are α-particles or ions of some sort they do not combine a sufficient penetrating power with a sufficient magnetic deflectibility to explain the height and structure of the aurora, and if they are electrons their penetrating power may be too great. It is therefore suggested that the aurora is due to ultraviolet light of the sun which produces ions and electrons in the high atmosphere of the earth, above 200 km. or so. These diffuse along the magnetic lines of force, concentrate at the magnetic poles of the earth, recombine and in some way yield up their energy to form the aurora. The aurora illumination during the strong display of August 20, 1927, was observed to be somewhat weaker than the light of the crescent moon, and from this the total energy of the aurora was estimated to be 10^{15} erg sec^{-1}. This is in rough agreement with the energy of photo-electric ionization in the high atmosphere indicated by wireless telegraphy, according to some recent calculations.

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* Phys. Rev. 31, p. 1038, 1928.

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SUR LA RECHERCHE DES RELATIONS ENTRE LES PERTURBATIONS MAGNÉTIQUES ET L'ACTIVITÉ SOLAIRE

par

Ch. MAURAIN

Parmi les phénomènes terrestres, ce sont les phénomènes magnétiques qui présentent les relations les plus certaines avec l'activité solaire. Et cependant, lorsqu'on cherche à préciser ces relations et à en analyser le détail, on se heurte à de grandes difficultés. Pour faire progresser les connaissances sur ce sujet, on peut utiliser les observations de deux manières : 1° Etudier les cas particuliers, c'est-à-dire la correspondance entre un phénomène solaire déterminé et un phénomène terrestre déterminé ; 2° Entreprendre des études statistiques portant sur des périodes assez longues, en tenant compte de toutes les observations.

La première méthode est évidemment très séduisante. Mais une coïncidence ou un petit nombre de coïncidences analogues ne suffit pas pour établir une relation, parce que ces coïncidences peuvent être dûes au hasard. Par exemple, on cite souvent l'observation de Carrington de 1859 : au moment même où il vit un phénomène lumineux intense dans un groupe de taches solaires, se produisait une forte perturbation magnétique. Depuis ont été notées quelques coïncidences analogues, mais en petit nombre. On peut se demander si, les perturbations magnétiques étant assez fréquentes, il n'a pas pu arriver que des coïncidences se produisent entre un phénomène solaire et une perturbation magnétique sans lien direct avec ce phénomène. Il semble qu'il faudrait un grand nombre de coïncidences de ce genre pour qu'on pût affirmer qu'il y a une relation directe entre certains phénomènes lumineux sur le soleil et des perturbations pratiquement simultanées du champ magnétique terrestre. Un fait beaucoup plus général est l'existence d'un intervalle de temps de l'ordre de deux jours entre le passage d'une tache ou d'un groupe de taches au méridien central du Soleil et une perturbation magnétique.

La deuxième méthode, celle des études statistiques, a conduit depuis longtemps à des résultats indiscutables, parmi lesquels le plus caractérisé est que l'amplitude des variations diurnes des éléments magnétiques est plus grande aux époques

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de maximum d'activité solaire qu'aux époques de minimum. La relation entre les perturbations magnétiques irrégulières, c'est-à-dire l'agitation magnétique, et l'activité solaire, est beaucoup moins nette que la précédente. Les fortes perturbations magnétiques sont en général plus nombreuses aux époques de maximum d'activité solaire qu'aux époques de minimum, mais le parallélisme numérique des deux phénomènes est beaucoup moins marqué que pour l'amplitude magnétique diurne et l'activité solaire. Dans une étude statistique portant sur 41 années d'observations aux environs de Paris (Observatoires du Parc Saint Maur et du Val-Joyeux ; Annales de l'Institut de Physique du Globe et du Bureau Central de Magnétisme Terrestre, t. V, p. 86-109, 1927) j'ai comparé aux caractères numériques moyens annuels ou mensuels des taches solaires (nombre de Wolf et Wolfer) d'une part les écarts diurnes moyens pour la déclinaison et les composantes horizontale et verticale du champ magnétique terrestre, d'autre part le nombre des ournées à perturbation magnétique. La première correspondance est très nette, alors que la seconde est très irrégulière. Cette irrégularité apparaît dans le détail de la comparaison : aux époques de faible activité solaire, des journées à perturbation magnétique correspondent parfois à une absence complète de taches solaires visibles, non seulement le jour de la perturbation magnétique, mais aussi pendant plusieurs jours auparavant et plusieurs jours ensuite.

J'ai cherché comment l'activité solaire se répartit, en moyenne, autour des perturbations magnétiques. A cet effet j'ai dressé un tableau des valeurs caractérisant l'activité des taches solaires pour chacune des journées à perturbation magnétique et pour chacune des cinq journées précédentes et des trois journées suivantes. Les valeurs de l'activité solaire pour les neuf journées qui englobent ainsi une journée de perturbation magnétique se présentent de manières très diverses, mais une répartition très nette apparaît si on fait les moyennes générales pour toutes les journées de même rang : on constate que la moyenne de l'activité solaire passe par un maximum qui est environ deux jours et demi avant les journées à perturbation magnétique. Cet intervalle de temps est variable avec l'époque des périodes de l'activité solaire : il est plus grand aux époques de minimum d'activité solaire, pour lesquelles il atteint trois jours trois quarts.

Les deux genres de méthodes que j'indiquais plus haut permettent d'établir l'existence de l'influence de l'activité solaire sur un phénomène terrestre, la première par des constatations isolées, la seconde en manifestant que le phénomène terrestre considéré présente les mêmes périodes que l'activité solaire, ou, plus exactement, que les taches solaires qui en sont une manifestation ; à ces taches sont liées deux périodes : la période undécennale et la période correspondant à la rotation

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des taches autour du soleil. Une fois une telle influence établie, pour en rechercher le mécanisme, il y a intérêt à étudier les autres variations périodiques présentées par le phénomène terrestre considéré ; celles qui se présentent naturellement sont la variation annuelle et la variation diurne.

L'agitation magnétique présente une variation annuelle très nette ; mon étude statistique portant sur 41 années d'observations donne, en accord avec les résultats d'autres auteurs, une variation annuelle de la fréquence des perturbations magnétiques présentant deux maximums ; j'ai trouvé, pour Paris, l'un vers le 7 ou 8 mars, l'autre vers le 7 ou 8 octobre. L'inclinaison de l'axe de rotation du soleil sur le plan de l'ecliptique, qui intervient dans l'origine de cette variation, ne peut pas l'expliquer complètement, et on est conduit à admettre un rôle des saisons terrestres, c'est-à-dire de la variation saisonnière des propriétés et des mouvements de l'atmosphère. D'ailleurs, plusieurs auteurs ont mis en évidence une variation diurne de l'agitation magnétique, qui présente un maximum vers le milieu de la nuit ; cette variation ne peut être rattachée à aucune variation solaire, et est forcement liée aux variations diurnes des propriétés de l'atmosphère.

Il y aurait intérêt à savoir de manière aussi précise que possible comment ces variations diurne et annuelle se présentent aux différents points de la Terre, ainsi que les variations diurne et annuelle des aurores et des courants telluriques. La répartition de ces variations donnerait des éléments précieux pour l'interprétation de l'action probablement complexe de l'activité solaire sur le magnétisme terrestre.

Avril 1928.

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PROBLEME DER AUSBREITUNG DER RADIOWELLEN

A. MEISSNER

Die Entwicklung zwingt uns heute auf keinem anderen Gebiet so zur internationalen Zusammenarbeit, wie bei der Untersuchung der Ausbreitungsvorgänge der langen und vor allem der kurzen Wellen. Es liegt dies nicht so sehr an der Fülle der noch zu lösenden Probleme, als vielmehr an der Notwendigkeit, die Untersuchungen über die ganze Erde, über alle Erdteile zu erstrecken. Nur Untersuchungen über grosse Entfernungen über 1000 de von Kilometern können uns die Klärung der Grundlagen bringen.

Was hier zunächst am dringendsten ist, ist das Sammeln von rein praktischen Erfahrungstatsachen, wie sie die drahtlose Technik für ihre Arbeiten auf grosse Entfernungen braucht. An die vollkommene theoretische Klärung der Ausbreitungsvorgänge können wir heute noch nicht denken ; selbst, wenn alle unsere Radio-Forscher und-Techniker mitarbeiten, werden wir sie erst in Jahren gefunden haben.

Für die langen Wellen und die Störungen bei den langen Wellen haben wir heute nach 20-jährigem Arbeiten, Beobachten und Sammeln bald das für die Technik notwendige Material zusammen. Auch für den Wellenbereich 1000 m. bis 100 m. dürften wir bald genügend technische Unterlagen besitzen. Alle die vielen Rundfunksender werden uns wohl in Kürze so viele Erfahrungstatsachen gegeben haben, dass wir auch dieses Gebiet technisch beherrschen.

Weit ab von der technischen Beherrschung sind wir aber noch bei den kurzen Wellen, den Wellen unter 100 m. Trotz der so umfangreichen Anwendung der kurzen Wellen ändern sich heute noch die primitivsten Grundanschauungen sowohl in Bezug auf die Sender, als auch in Bezug auf die Empfänger. Vor kurzem arbeitete man nur mit vertikalen Antennen. Heute dagegen geht man in Deutschland dazu über, fast ausschliesslich horizontale Antennen und horizontale Polarisationen zu verwenden. Die letzten Versuche zeigten hier, dass die horizontalen Antennen mit zunehmender Höhe über dem Boden (h $\lambda/4$) zusehends besser werden als die vertikalen Antennen. Insbesondere zeigte sich diese Ueberlegenheit bei der Verwendung von gerichteten Antennen. Hier wird bei horizontaler Polarisation für die Konzentration der Strahlung im Horizontalkreis eine grosse Zahl von horizontalen gleichphasig erregten Antennen in einer Linie verwendet. Für die Konzentration im Vertikal-

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kreis wird ein Parabelreflektor verwendet, oder, da sich herausgestellt hat, dass der günstigste Ausstrahlwinkel für die Wellen über 15 m. 0° bis 20° beträgt (gemessen gegen die Tangentialebene der Erde im Senderort), wird technisch meist zweckmässiger ein System für horizontale Antennen übereinander in einer zur Erdoberfläche senkrechten Fläche, mit einer ebensolchen Reflektorfläche in 1/4 Wellenlänge Abstand dahinter verwendet. Die Bestimmung des günstigsten Ausstrahlwinkels am Sender gehört mit zu den wichtigsten Versuchs-Ergebnissen der letzten Zeit. Die Untersuchungen konnten hier nur mit horizontalen Antennen und Parabelreflektoren durchgeführt werden. Bei Vertikalantennen ist es schwierig, den Ausstrahlwinkel festzustellen, da alle Antennenanordnungen in unübersichtlicher Weise vom Erdboden beeinflusst werden. Bei Horizontalantennen lag der günstigste Ausstrahlwinkel bei einem System für 11 m. anscheinend bei etwa 35°. Neuere Versuche bei 15 m. ergaben, dass der Winkel bei $\lambda = 15$ m. etwa zwischen 10 und 20° liegt, bei $\lambda = 20$ m. liegt er um 0° also so, wie ihn Eckersley auf Grund seiner früheren Versuche mit vertikalen Antennen angenommen hat. Da bei Versuchen mit dem Parabolreflektor die Oeffnungsweite der Parabel nur etwa λ betragen hat, so ist anzunehmen, dass tatsächlich der Ausstrahlwinkel durch den bei der geringen Oeffnungsweite der Parabel doch immer vorhandenen Erdeinfluss, die Induktion im Erdboden unmittelbar am Sender grösser als 0° war.

Ueber den günstigsten Einstrahlwinkel am Empfänger besitzen wir noch keine Klarheit. Für etwas längere Raumstrahlwellen als 100 m. hat Appleton den Winkel bestimmt. Für die Wellen unter 100 m. wird jetzt versucht, auch hier den Winkel mit horizontalen Antennen und Drehreflektoren zu erfassen. Am Empfänger liegen freilich die Verhältnisse viel komplizierter als beim Sender. Vielfach ist im Empfang die horizontale Antenne besser, vielfach die vertikale. Oft tritt die Eigentümlichkeit der Drehung der Polarisationsebene der Strahlung auf. Besonders auffällig ist hier, dass man beim Senden mit horizontalen Polarisationen an der Empfangsstelle in grösserer Entfernung immer dieselben Polarisationsverhältnisse erhält, wie beim Senden mit vertikaler Polarisation. Die meisten Schwierigkeiten im Empfang bieten uns heute die Fadings. Die Feststellung ihrer Abhängigkeit von meteorologischen, örtlichen, den erdmagnetischen Einflüssen, wird uns noch auf Jahre hinaus beschäftigen. Das, was heute festzustehen scheint, ist, dass die Fadings an Orten verschieden sind, die oft nur wenige Wellenlängen auseinander liegen, dass sie verschieden sind an horizontalen und vertikalen Antennen, verschieden bei verschiedenen Wellen, verschieden in den verschiedenen Tages- und Jahreszeiten. Die Zusammenhänge fehlen uns hier noch.

Eine nur bei den Wellen bis etwa 44 m, hauptsächlich bei

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den Wellen unter 20 m. auftretende Störerscheinung sind die « Doppelzeichen ». Sie machen den Tagesverkehr, insbesondere im Wellenbereich zwischen 15 und 20 m., oft auf Stunden unmöglich. Die deutsche Transradio-Gesellschaft (Quäck) macht auf diesem Gebiet seit 1 1/2 Jahren eingehende Beobachtungen. Im Winter nehmen diese Doppelzeichen ihren Weg in der Hauptsache nach der Rückseite des Senders, im Sommer nach der Vorderseite des Senders, oft 2 bis 3 Mal um die Erde herum wandernd. Die Erscheinung der Doppelzeichen zeigen bei Empfang in Berlin die Tagessender von allen Himmelsrichtungen. Hauptsächlich scheinen sie vorhanden zu sein, wenn Sender und Empfänger im Bereich einer gemeinsamen Dämmerungszone liegen, jedoch gibt es auch hier Abweichungen. Es wurden auch Doppelzeichen beobachtet, die anscheinend den ganzen Weg durch die Nacht genommen hatten, Dies entspräche einer Skip-Distanz = 1/2 Erdumfang. Die Bahnen der Doppelzeichen scheinen in einer Entfernung von der Erdoberfläche zu verlaufen, die einem 3,5% grösseren Erdumfang entspricht. Es ist aber heute wohl noch verfrüht, aus den bisherigen Beobachtungen Schlüsse auf die Höhe der übertragenden Schichten oder die Geschwindigkeit der Ausbreitung zu ziehen.

Das für die Technik wichtige Problem der Bestimmung der günstigsten Wellen für die verschiedensten Jahres-, Tageszeiten und Entfernungen, findet dadurch automatisch seine Lösung, dass schon heute fast das ganze Wellenband von 14-100 m. mit einer Unzahl von Sendern aller Länder besetzt ist, aus deren Arbeiten und Verkehr sich genügend Material für die einzelnen Wellen ansammelt; schon heute sieht man, dass vorläufig eine Systematik hier noch ziemlich schwierig ist. Wohl gelten im allgemeinen als Tageswellen die Wellen bis ca. 20 m., als Nachtwellen die Wellen über 19 m. Aber häufig findet man, dass die kürzeren Tageswellen ganz ausgezeichnet auch die ganze Nacht hindurch arbeiten.

Grössere Unsicherheiten bestehen noch für das Gebiet unter 14 m. Hier wurde die Welle 11 m. im Tagesverkehr mit Süd-Amerika von Berlin aus längere Zeit versucht. Es ergab sich, dass diese Welle in den Monaten September-Januar meistens den anderen Wellen stark überlegen war, vom Januar-Juni war sie ebenfalls meistens überlegen, aber 25% der Tage, in denen die etwas längeren Tageswellen gar keine Veränderungen zeigten, war die 11 m. Welle im Empfang nicht vorhanden; in den Monaten Juni-September war sie meistens wesentlich schlechter oder überhaupt nicht zu finden. Die 8 m. Welle versagte im Verkehr mit Süd-Amerika vollkommen. Dagegen zeigte es sich bei den Versuchen, diese Welle von Berlin aus in Süd-Amerika zu empfangen, dass man gut die Oberschwingungen der nord-amerikanischen Kurzwellensender (9 m., 8 m., 7 m.) in Süd-Amerika empfangen konnte. Man könnte danach

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annehmen, dass man in der Richtung Nord-Süd mit diesen Wellen, vielleicht auch noch mit 2 bis 5 m., wird arbeiten können. — Mit den Wellen unter 3 m. sind bisher nur Empfangsversuche auf einige 100 km. gemacht worden. Bei diesen Entfernungen scheint es bei der 3 m. Welle von Wichtigkeit zu sein, die Lage des Senders sorgfältig auszuwählen und vor allem den Sender hochzustellen. Bei noch kürzeren Wellen scheint man noch mehr von den besonderen Zuständen am Sendeort und besonders denen der Atmosphäre abzuhängen. Zufälligkeiten in der Zusammensetzung der Atmosphäre bewirken hier nur zu oft Störungen. Im Wellenbereich unter 3 m. kann man anscheinend sehr schöne Experimente machen, aber für eine Verkehrszuverlässigkeit reichten die bisherigen Ergebnisse nicht aus. Wieweit die Grenzen der technischen Anwendbarkeit der kürzesten Wellen sich nach unten verschieben lassen werden, ist heute noch nicht zu übersehen. An sich wären die kürzesten Wellen unter 10 m. deshalb für die Empfangstechnik sehr zweckmässig, weil mit kürzer werdender Welle die atmosphärischen Störungen noch ganz wesentlich abnehmen. Dieser Gesichtspunkt der Verminderung der atmosphärischen Störungen wird heute freilich von der Kurzwellen-Technik noch nicht so in den Vordergrund geschoben wie bei den langen Wellen, da die anderen Störungen (Fadings usw) den Empfang heute noch so wesentlich mehr beeinträchtigen, als die atmosphärischen.

In Zusammenfassung aller Beobachtungsresultate der Kurzwellen-Technik sehen wir, dass wir heute noch weit ab von klaren Vorstellungen und Theorien über die Ausbreitungsvorgänge sind. Das rohe Bild, dass wir uns heute von der Kurzwellenübertragung machen können, ist, dass die Kurzwellenstrahlung innerhalb unserer 300 bis 600 km. hohen Atmosphäre gehalten wird und nichts, oder nur verschwindende Bruchteile der Energie nach aussen dringen. Die Beugung der Strahlung ist hier bewirkt durch den ganzen ionisierten Bereich der Atmosphäre. Wir können nur sagen: Der Vorgang hat sehr viel Aehnlichkeit mit der Beugung des Lichtes auf grosse Entfernungen (Kimmung, Fata-Morgana, Szintillation), Die Lichtbeugung basiert auf der Aenderung der Dielektrizitäts-Konstante durch Aenderung der Dichte der Atmosphäre. Bei den kurzen Wellen basiert die Beugung auf der Aenderung der Dielektrizitäts-Konstante durch Aenderung des Jonen- bezw. Elektronen-Gehaltes der Atmosphäre. Die Aenderung der Dichte mit steigender Höhe, die in der Optik die Ausbreitung auf grosse Entfernungen bedingt, ist eine Störung des Normalzustandes, die Aenderung der Jonisation mit steigender Höhe bei den kurzen Wellen ist dagegen der Normalzustand der Atmosphäre. Die Ursache der Jonisationen (Jonen und Elektronen) ist so überwiegend die Sonnenlichtstrahlung, pass man wohl zunächst, um sich die theoretische Aufgabe nicht

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zu sehr zu erschweren, alle anderen Jonisationsursachen vernachlässigen kann.

Der Einfluss des normalen erdmagnetischen Feldes ist bei den Wellen über 100 m. noch nicht festgestellt worden; bei den Wellen unter 100 m. verursachen die Schwankungen des Erdfeldes sehr starke Empfangsstörungen. Das konstante Erdfeld ist vielleicht die Ursache, dass die Kurzwellen-Verbindung Amerika-Europa, besonders die Verbindung von Europa nach Amerika, wesentlich schlechter arbeitet als die anderen Kurzwellenverbindungen.

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MEASUREMENTS OF ULTRA-VIOLET SOLAR RADIATION 1924-1928

by

Edison PETTIT

A series of measurements of ultra-violet solar radiation were begun in 1924 with the thermocouple. The principle consists in measuring the ratio of the ultra-violet radiation transmitted by silver (λ 0.32 μ) to that transmitted by gold (λ 0.5 μ) with a thermocouple attached to a D'Arsonval galvanometer, which registers its deflections on a moving photographic plate every minute. The metallic films are deposited on the surface of a quartz lens of focal length two and one half inches and on the surface of a quartz plate, the two being mounted in a cell in such a way that the films are on the inside to protect them from atmospheric attack. Protected in this manner the films are constant in transmission properties, and neither the metallic films nor the quartz is affected by sunlight. The same films have been used throughout the work. The cells have been taken apart on several occasions and the films show no signs of tarnish or other defects. The whole apparatus is mounted on an equatorial provided with a self winding clock.

On a clear morning in mid-summer more than a hundred values of the ratio ultra-violet to green solar radiation are obtained, and in mid-winter about seventy. The logarithm of the ratios plotted against secant Z, obtained from the hour angle photographed on the plate, gives a straight line which may be extrapolated to the zenith or no atmosphere. The latter values are an index of the ratio ultra-violet to green solar radiation at the Sun itself. Since the ratio of monochromatic light in two regions of the spectrum is being measured, no account need be taken of sky radiation or eccentricity of the earth's orbit. Faulty guiding of the equatorial, thin clouds and other disturbances produce only differential errors on the ratio. A direct test with an ozone tube shows that variations in the ozone content of the atmosphere have a negligible effect on the result.

During the summer and autumn of 1924 the apparatus was run on only 37 days, to test its action and the conditions of observing. It was then taken down for re-modelling and a daily series of measurements were begun in April 1925, and this program has been continued without interruption to the

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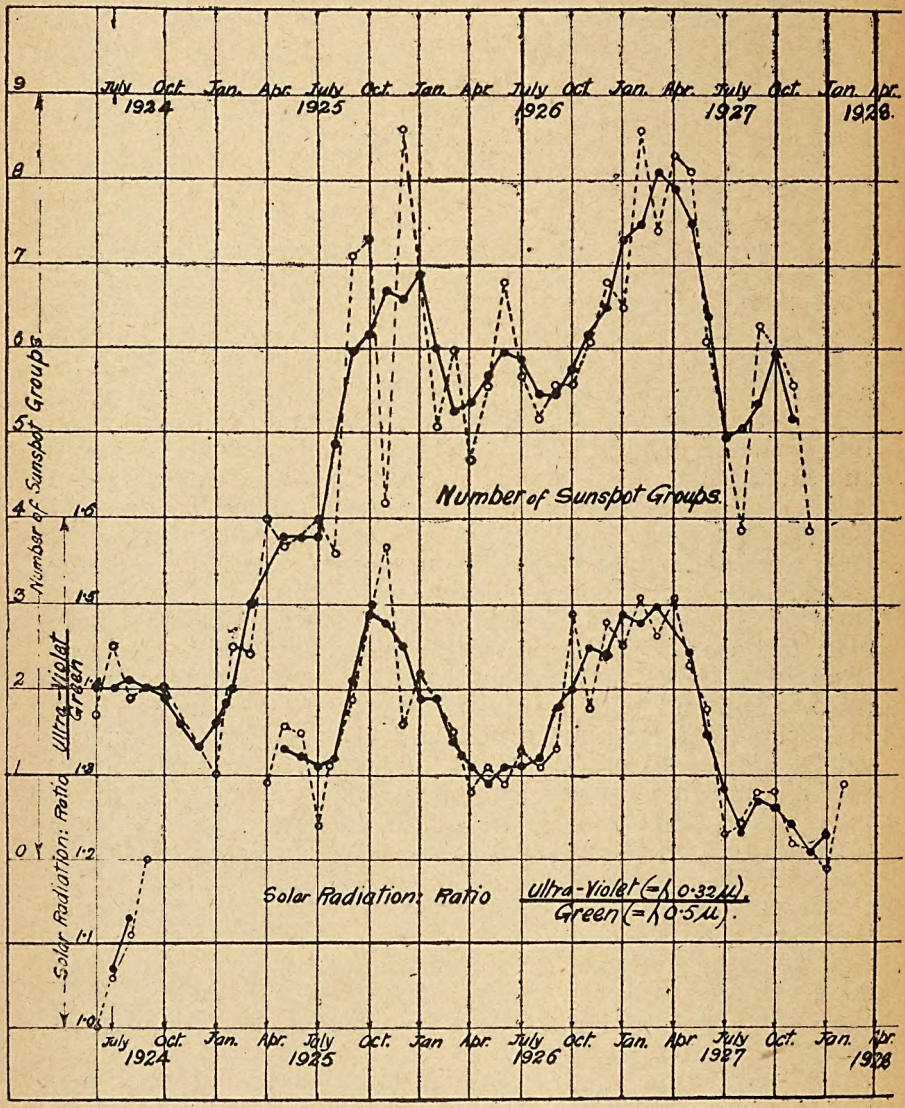

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present time. The monthly means have been plotted and the curve smoothed with running three month averages. The monthly average of the daily sunspot group numbers were treated in like manner.

TABLE I

DATE	RATIO U.V./GREEN	Nº. SPOT GROUPS
1924 July	1.00	2.0
1925 July	1.31	3.8
Oct.	1.49	6.2
1926 Jan.	1.39	6.9
Apr.	1.31	5.4
July	1.31	5.9
Oct.	1.40	5.8
1927 Jan.	1.47	7.3
Mar.	1.50	8.1
Apr.	1.47	7.9
July	1.28	5.0
Oct.	1.27	6.0
1928 Jan.	1.23	5.3

Table I shows the values of the ordinates for the beginning of each third month, and the plot in figure I shows the comparison of both the smoothed (full lines) and the unsmoothed (dotted lines) monthly means. The unsmoothed monthly means reached a maximum of 1.57 in November 1925 ; there was a slump during 1926 to a minimum of 1.28 and another maximum of 1.51 in the winter of 1926-27. A decline then set in which has now (January 1928) reached the low value of 1.19. The most violent disagreement between the monthly averages was in November and December 1925, but the general trend of the curves, especially when smoothed with three-month averages, has been quite similar.

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SOME CORRELATIONS OF RADIO RECEPTION WITH ATMOSPHERIC TEMPERATURE AND PRESSURE *

by

Greenleaf W. PICKARD *

The first definite correlation between radio reception and any measured atmospheric state was made by Austin in 1924 (1). Comparing air temperatures with day reception at Washington from low frequency stations in New Jersey he found an inverse relation, which was particularly marked with cold waves. Early in my measurements of night reception in the broadcast band I examined pressure gradients between transmitter and receiver without finding a definite relation to reception (2). But when a homogeneous series of reception measurements extending over a period of two years had accumulated, meteorological relations began to appear, particularly with temperature and pressure.

Two series of reception measurements were available for this comparison : my own of station WBBM at Chicago as received in Newton Centre, Massachussetts, and those of Mr. Howell C. Brown at Pasadena, California, of transmission from station KWFI at San Francisco. Mr. Brown's measurements are of peculiar value in this work, as his transmission path (perhaps because it has a considerable component parallel to the Earth's magnetic field) appears but little affected by solar activity and magnetic disturbances. Unfortunately, although my measurements over a West-East path now cover a period of over two years, the California series began in July 1927, and is as yet too short for a really satisfactory comparison.

The following statements summarize the results obtained : Night reception and temperature at the receiver are found directly related, maximum reception being associated with

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*Summary of a paper presented before the International Union of Scientific Radio-telegraphy, Washington, D.C., April 19, 1928.

(1) Proceedings of the Institute of Radio Engineers, 12, page 681, December 1924 ; 14, page 781, December 1926.

(1) Proceedings of the Institute of Radio Engineers, 15, page 95, February 1927.

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maximum temperatures and vice versa. This is the reverse of the relation previously found by Austin for day reception, where falling temperature improved reception, and is therefore another case of the already established inverse relation of night to day reception. The temperature effect appears to be local to the receiver, for no definite relation was found between temperature at the transmitter and reception. A correlation between night reception and pressure was also found, signal strength increasing as areas of low pressure passed over the receiver, and decreasing with the passages of high pressure.

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SOME RECENT WORK ON THE LIGHT OF THE NIGHT SKY

by

Lord RAYLEIGH

Introductory

It is now well known that the light of the night sky has little in common with the day sky. When the sun is 18 degrees below the horizon, and the moon also below the horizon, night conditions may be considered to be established. A clear sky is of course necessary for the study of the luminosity. It is found to exhibit very little polarisation. The intensity is considerably below the threshold of colour vision, and subjective impressions about its colour, which is sometimes described by imaginative writers as blue, have no basis in reality. Its chromatic constitution can be investigated by experiments with coloured glasses. We may select a red and a blue glass, and look through them at the night sky. The blue one will almost certainly be the brighter, owing to the Purkinje effect. We may superpose neutral glasses on the blue one until the intensities are matched, and we shall then have a test by means of which the night sky can be compared qualitatively with other sources as regards the blueness or redness of the light. It is only necessary to reduce the intensity below the threshold of colour vision, and to note which glass gives the brighter field. It is found in this way that the day sky is much bluer than the night sky, which is nearly of the general colour of a piece of white paper illuminated by a half watt lamp at normal incandescence. In this comparison, the brightness of the paper may be suitably reduced by placing the lamp a long way off.

Spectrum of the Night Sky

Spectroscopy of the night sky is a difficult problem, and the most that can be made out by visual methods is that the green auroral line is present on a background of apparently continuous spectrum. Some writers have recorded that they can always see the green line. The present writer can only see it when the brightness, as revealed by the photometric method presently to be described, is above the average. Many experienced

* Received for publication June 18 th 1928.

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spectroscopists have been unable to see it at all. The main instrumental condition is to use a wide slit and a high dispersion. Lenses may advantageously be dispensed with.

Photographic methods are necessary for a more detailed study of the spectrum. In a single night's exposure it is scarcely possible to do more than photograph the green line using a one prism spectrograph with aperture ratio not less than $f/2$ and an orthochromatic plate. The writer has constructed small spectrographs with an aperture ratio $f/0.9$, and with these it has been possible, with an exposure of many nights, to photograph the apparently continuous background of the spectrum, along with two emission lines or bands at wavelengths very roughly estimated as 4210 and 4430. The broad absorption lines *G*, *H* and *K* of the solar spectrum are seen in absorption. These are probably to be attributed to starlight, which is superposed on the light proper to the night sky. The relative amount of starlight has not been determined. It is believed by the writer to be largest in the blue region of the spectrum, and relatively unimportant in the yellow and red regions.

An exposure of many nights on an Ilford panchromatic plate failed to show anything in the red region of the spectrum.

It is noteworthy that the negative bands of nitrogen, which are the most important feature in photographs of the auroral spectrum, are not present in the night sky.

Photometric Methods of observation

For some years past the writer has been making systematic photometric observations on the light of the night sky. As we have seen, the spectrum consists partly of the green auroral line, and partly of apparently continuous background. It is desirable to treat these separately. The light is however too feeble to allow of spectrophotometry in the ordinary sense. The method adopted in this work is to analyse the light with colour filters. Three filters were used, one designed to isolate the green auroral line as nearly as possible, and the others designed to transmit the region (*a*) on the red side, and (*b*) on the blue side of the line, excluding the line itself in each case. These are called the red, auroral and blue filters.

The standard comparison light consists in each case of crystals of potassium-uranyl sulphate, which are self luminous, owing to the radioactivity of the contained uranium, which stimulates the fluorescence of the salt. There is reason to believe that when in a sealed vessel the source may be regarded as independent of external conditions, and constant, at all events for very many years.

The type of photometer chiefly used consists of a Lummer cube, with the field divided into two vertical strips. The right hand (transparent) is backed by the uranium salt. The left hand part, silvered, reflects the sky with a colour filter inter-

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posed. Choice from a series of neutral glasses allows the filtered sky light to be matched with the standard.

The densities ($\log_{10}$ opacity) of the set of neutral glasses had the values

0.1 0.2 0.3..... 0.7 etc.

The scale used for recording and discussing the results is a magnitude scale, i.e., one in which each step is a constant multiple of its predecessor. The zero reading is that which gives a match without one of the neutral glasses. A reading of (e.g.)+3 means that the third neutral glass has to be used *over the sky*. A reading is recorded as —3 if the same glass has to be used *over the uranium source*. Intermediate interpolated values are entered as, e.g., 3.5. The zeros for the three separate regions of the spectrum, red, auroral, blue, are related in an arbitrary manner, though the factor involved in passing from one neutral glass to the next is, of course, the same for each, so far as the glasses deserve the same neutral. Within the practical limits of experimental error, they do deserve it.

Is is to be noticed that the comparisons are not at all prejudiced by a difference in colour between the two lights. At these low intensities the eye sees everything in monochrome, just as the photographic plate does at all intensities.

If the intensities are to be compared at different places and at the same time, it is necessary to duplicate the instruments and to adopt one as a master standard. The others can be compared with it by means of an " artificial sky " consisting of a diffusing screen of which the brightness can be controlled and measured by varying the voltage across the terminals of a small electric lamp used to illuminate it. The details are here passed over. Each local observer takes the readings with his own instrument, as described. They are reduced to the standard scale at headquarters by applying a subtractive correction, which gives the result which would be obtained under the same conditions on the master standard instrument, with the filters belonging to the latter. The scale numbers thus adopted are those of the neutral glasses, thus the intensity is multiplied by passing up one unit by the antilogarithm of 0.1 or 1.259. Three steps on the scale are equivalent to a factor of $(1.259)^3$ or to approximately a doubled intensity. This is a convenient rule to remember.

Photometric Observers and Results

For observations in various parts of the world I have been able to rely on the kindness of scientific friends who either undertook the work themselves or were able to find other capable observers who were so kind as to undertake it.

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The stations and observers were as below :

HAWAII.
United States Magnetic Observatory, Ewa, Oahu.
Observer. Mr. H.E. McComb.
VICTORIA. BRITISH COLUMBIA.
Dominion Observatory.
Observer. Dr. J.S. Plaskett, Mr. Harper, Mr. H.H. Plaskett, Mr. Pearce.
MOUNT. WILSON, CALIFORNIA.
Observer. Mr. Humason (as arranged for by Mr. H.D. Babcock).
POMONA COLLÈGE, CLAREMONT, CALIFORNIA.
Observer. Prof. Brackett.
PINEHURST, N. CALIFORNIA.
Observer. Prof. J.C. McLennan.
KINGSTON, ONTARIO.
Observations received though Prof. J.C. McLennan.
AREQUIPA, PERU.
Observers. Dr. J.S. Paraskevopoulos (as arranged by Prof. Harlow Shapley)
LERWICK OBSERVATORY, SHETLAND ISLANDS.
Mr. A.W. Lee (arranged by Dr. G.C. Simpson).
ENGLAND.
At Terling, Essex, and Near Hexham, Northumberland, during part of the autumn. Observations by the writer.
CAPE OF GOOD HOPE.
Observer. Dr. H. Spencer Jones.
GILGIL, KENYA COLONY, E. AFRICA.
Observer. Mrs. G. Cole.
KODAIKANAL OBSERVATORY, INDIA.
Observers. Dr. Royds, Mr. A.A. Narayana Ayer, Mr. P.R. Chidambara Ayer Mr. S.S. Ramaswamy Ayyangar.
CANBERRA, AUSTRALIA.
Commonwealth Solar Observatory.
Observers. Dr. W.C. Duffield and Mr. A.L. Kennedy.
CHRISTCHURCH, N. ZEALAND.
Observer. Mr. P.W. Glover.
VOYAGE FROM MARSEILLES TO BOSTON.
Observer. Mr. H.D. Babcock.
VOYAGE FROM ENGLAND TO MELBOURNE.
Observer. Miss Natalie Allen.

MEAN VALUES AND RANGE OF VARIATION

The following table gives the mean results in each component. It must be emphasised that though the red component (e.g.) is measured throughout on a consistent scale, this scale has an arbitrary difference from the scale used for either of the other components ;

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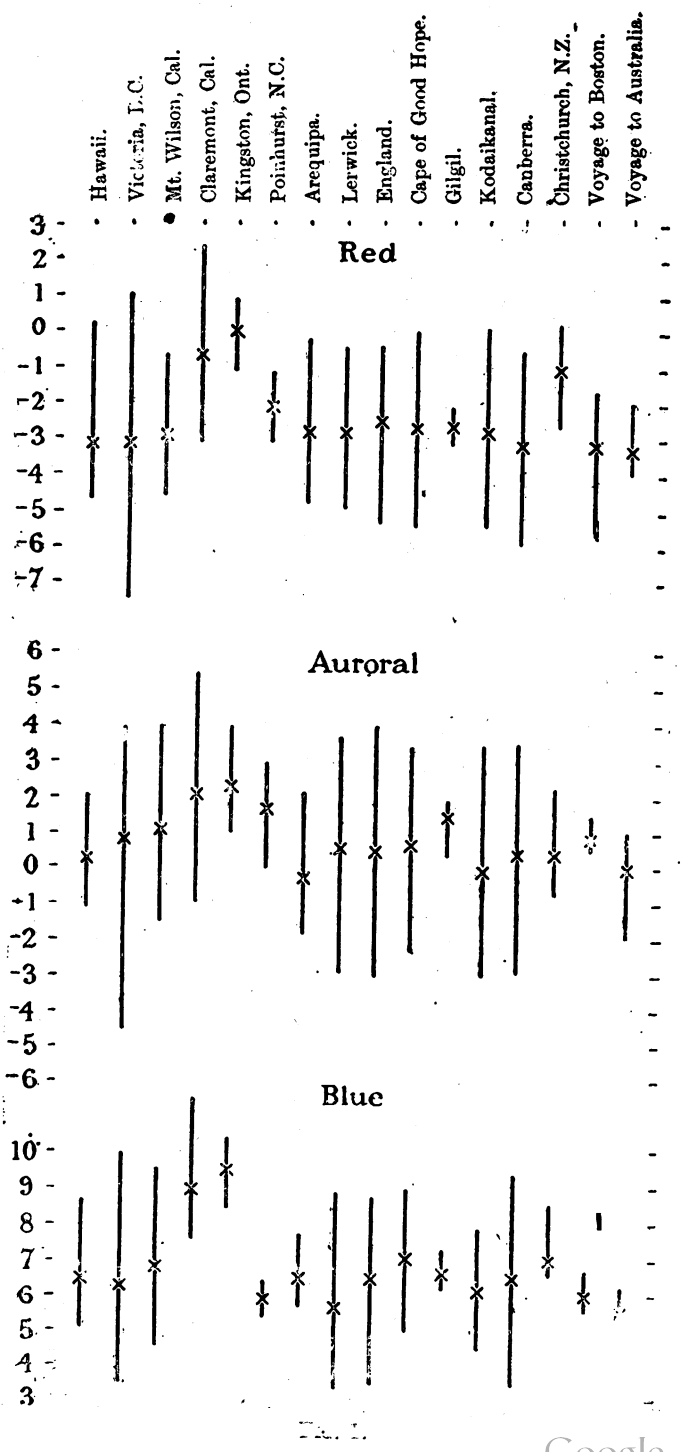

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this difference representing an arbitrary but constant intensity ratio

STATION	RANGE IN TIME	TOTAL NUMBER OF OBSERVATION NIGHTS	MEAN VALUES		
			RED.	AURORAL.	BLUE.
HAWAII	Oct. 1925 to Nov. 1926.	116	—3.2	+0.3	+6.5
VICTORIA	Sept. 1925 to Mar. 1927.	108	—3.2	+0.8	+6.3
MOUNT WILSON	Sept. 1925 to Feb. 1927.	83	—2.9	+1.1	+6.8
CLAREMONT	Oct. 1925 to Feb. 1926.	57	—0.7	+2.1	+8.9
PINEHURST	January 1926.	3	—2.1	+1.7	+5.9
KINGSTON	April 1926 to May 1926.	6	+0.1	+2.3	+9.5
AREQUIPA	April 1926 to Nov. 1926.	31	—3.1	—0.3	+6.5
LERWICK	Sept. 1925 to April 1927.	86	—2.8	+0.6	+5.7
ENGLAND	Nov. 1925 to Oct. 1926.	81	—2.5	+0.5	+6.4
CAPE	Nov. 1925 to Nov. 1926.	199	—2.7	+0.7	+7.1
GILGIL	September 1925.	5	—2.7	+1.5	+6.6
KODAIKANAL	Oct. 1925 to Jan. 1927.	54	—2.8	—0.1	+6.2
CANBERRA	Nov. 1925 to Oct. 1926.	149	—3.2	+0.4	+6.5
CHRISTCHURCH	Feb. 1926 to Feb. 1927.	56	—1.0	+0.4	+7.0
VOYAGE TO BOSTON	August 1925.	6	—3.2	+0.8	+6.0
VOYAGE TO MELBOURNE	September 1925.	10	—3.3	+0.0	+5.6

Fig. 1 shows graphically the mean values of the previous table, which are marked by crosses, with the extreme range in each component marked by the vertical lines.

The general conclusions to be drawn from this diagram appear to be as follows : Firstly, fairly normal values can be stated for the intensity of each component at any part of the world. These values are somewhat as follows, on the various arbitrary scales:

Red	— 2.5
Auroral	+ 0.8
Blue.....	+ 6.5

The few cases which apparently do not conform to this are believed to be due to observational causes. Full discussion is given in the Royal Society paper.

The usual range of variation is from three to four fold in any given component.

There is a strong correlation between the red and auroral intensities on any given occasion and a rather less strong, but still marked correlation between these and the blue. It is however definitely established that this correlation is not complete. A simple test for this is to match, e.g. a red glass directly against a blue one by the addition of suitable neutral glasses, discarding the use of the self luminous standard. It is found that this adjustment does not remain good for all succeeding nights, though it may be necessary to wait for some time before a marked change is observed.

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Are the Variations at different Stations correlated ?

The variations of intensity which form the subject of this investigation do not occur uniformly all over the world. They are conditioned in large part at any rate by local circumstances. To illustrate this, some striking cases will be given:

DATE	PLACE	RED	AURORAL	BLUE
January 16, 1926.	England	—4.4	—1.4	+5.8
	Cape	—1.9	+2.0	+9.0
March 2, 1926.	England	—3.6	—0.2	+6.4
	Cape	—0.4	+2.0	+7.7
April 15, 1926.	England	—3.6	—0.8	+6.4
	Cape	—2.4	+2.4	+8.3
September 19, 1925.	England (Northumberland).	—3.6	+1.7	+6.4
	Shetland (Lerwick)	—4.4	—2.8	+3.4
June 7, 1926.	Hawaii	—4.7	—0.9	+5.1
	Canberra	—2.4	+2.1	+7.9

These cases have been chosen to show contrast. The mean values at the two places are in each case very nearly the same. Yet we see that occasions may be found where the intensity at one is double or more than double that at the other.

On calculating the correlation coefficients for approximately simultaneous observations at the pairs of stations mentioned, no significant coefficients were found. It will be seen immediately that there probably are long period variations which imply a correlation, but these are swamped by local irregular variations.

Periodicities

An annual periodicity was early suspected in my own observations in England. At the time of writing, observations lasting over five years are available, so far as the auroral component is concerned. To examine impartially whether or not an annual variation is present, the observations of each calendar month (November, 1926, e.g.) are averaged, and the mean is adopted as representative of that particular month, without further reference to the data for individual nights :

	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL
1922-3 ...	—	—	—	—	—	—	—0.5	0.0	—1.9
1923-4 ...	+0.0	+0.3	+0.7	+0.0	—2.2	—2.2	—1.6	—0.3	—1.7
1924-5 ...	+1.0	+0.7	+1.6	—0.9	—0.8	—1.5	—1.2	—0.8	—1.8
1925-6 ...	+0.8	+0.9	+0.8	+1.5	+0.0	+0.5	—0.3	—0.4	—0.0
1926-7 ...	+0.5	+0.8	+1.3	+1.1	—0.4	—0.7	0.0	+0.8	—0.5
1927-8 ...	+2.0	+1.2	+1.8	+0.9	+1.0	—0.3	—	—	—
Sum	+4.3	+3.9	+6.2	+2.6	—2.4	—4.2	—3.6	—0.7	—5.9
Mean	+0.9	+0.8	+1.2	+0.5	—0.5	—0.8	—0.7	—0.1	—1.2

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The individual seasons and the mean are plotted in fig. 2.

Although the results are not numerous enough to give complete statistical regularity, yet I think it is difficult to resist the indications of a definite annual period. The great fall of intensity usually occurs between November and December. In each of the four complete observing seasons (August to April) the mean of all months before this date is much greater than the mean after it. This fall must have its counterpart in a recovery, which would naturally be taken to occur six months later, i.e. between May and June.

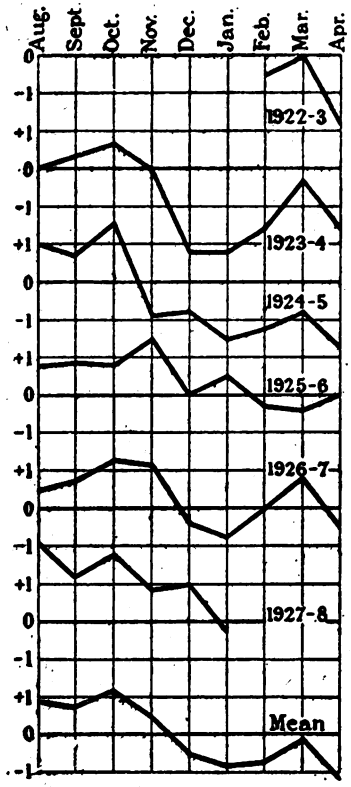

Fig. 2.

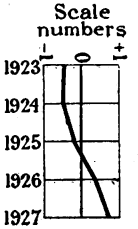

Fig. 3.

No observations can be made at that season, owing to residual daylight. But in every one of the five cases available* a considerable recovery has occurred at some time between April and August, in the interval when residual daylight prevents observations.

Special attention is directed to the mean curve at the bottom of fig. 2. which sums up the evidence for annual periodicity.

* This number is now extended to 6 (Oct. 1928)

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The amplitude of annual variation indicated is about 2 units or a factor of 1.6. The subordinate maximum in March may be due to coincidence of irregular variations, but it is well to keep an open mind on this point, particularly in view of certain magnetic periodicities.

Turning now to a second question, that of variation in the cycle of the sunspots, it is to be noted that the observations begin at about the time of sunspot minimum in 1923, and that according to present expectation, the maximum will be reached in the present year, 1928. By analogy of other phenomena known to depend on the spot-cycle, we should anticipate an increase in the light of the night sky during this period, if such an influence exists at all.

To eliminate any effect of the annual periodicity just discussed, it is necessary to compare the intensity in successive years at the same season. If we look at any given column in the table (October, e.g.), we find a tendency to increase with time, though this tendency is not strong enough always to assert itself, against the irregularities after the lapse of a single year. But, in every one of the nine columns, the last entry is substantially higher than the first. If the variations when cleared of the annual periodicity were quite unsystematic, the chance of this occuring would be only $_2{}^{-9}$, or 1 in 512.

For greater statistical regularity, we may take the mean of all the months in a given observing season, or in a given year. To include observations taken in the spring of 1923, and in the present uncompleted observing season, the latter course is adopted.

The result is shown graphically in Fig. 3.

The mean annual increase is 0.3 unit, representing a factor of 1.07. Thus the results clearly indicate a general yearly increase of the intensity during practically the whole period of observation, relative to the uranium standard. This could be explained away if we assumed a slow loss of brightness in the standard, but there are reasons which seem adequate for rejecting this explanation.

Returning to the question of annual periodicity, it seems probable that this depends on the Sun's motion in declination. If so, the effect should be negligible at the equator, and should show itself in the opposite phase in the southern hemisphere. There is some evidence from the available data that this is in fact the case.

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Polar Aurora

It is important to distinguish between the polar aurora occurring typically in the auroral zones, and the nonpolar aurora occurring all over the earth.

Both have the green line λ 5578 which has been shown by the work of McLennan and his colleagues to be due to oxygen, as the strongest feature of the visual spectrum. It may seem an arbitrary procedure to distinguish two separate phenomena when there is so much in common, and I know from correspondence and otherwise that some scientific men are unwilling to admit it. Nevertheless, after further experience and study, I am more than ever convinced that it is necessary.

The grounds on which this distinction was originally made were that the nitrogen bands (negative bands) occur only in the polar aurora ; that the polar aurora has a distinctive distribution in latitude which the other has not ; that the polar aurora often shows distinctive forms such as arcs and draperies, whereas the non-polar aurora is uniform ; while finally the polar aurora varies enormously in intensity in the course of a few minutes, whereas the non-polar aurora is often sensibly constant for days. I wish now to to discuss the subject from the standpoint of intensity measurements.

We find, in the majority of stations, where " auroral displays " rarely, if ever, occur, that the range of intensity observed through the auroral filter, which I take as a measure of the intensity of the green line, has a fairly definite mean value of about 0.4 on my scale, with a standard deviation of 1.0. It is true that this intensity is subject to a yearly, and probably also to an 11-yearly variation. But these variations are comparatively slight, and for the present purpose may be ignored.

Lerwick (Shetland), Victoria (British Columbia) and Kingston (Ontario) are stations where auroral displays are comparatively common.

At the Cape, or at Canberra, or Hawaii, they are practically unknown.

The case of England is intermediate. Auroral displays occur occasionally, though not often.

Let us consider what happens in this intermediate case, where the statistical issue can be most easily presented. In the year 1926 my observations in England on 75 nights, in the absence of an auroral display, give for the auroral intensity :

Range	—2.2 to +3.0
Mean value.....	+0.2
Standard deviation	1.1

Now, only one auroral display was observed when it was found that :

Auroral display gave.....	+16.0
Deviation from the mean.	+15.8

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thus giving an isolated deviation of no less than 14.4 times the standard. As is well known in all ordinary cases of statistical distribution, values three times the standard are nearly the highest that occur. A value 14.4 times the standard is fantastic and shows that we are attempting to classify in the same scheme values that are not properly comparable at all. In the case of barometric variations at sea level, such a deviation would mean a barometric beight of about 34.7 inches! This comparison shows that we must class auroral displays as quite a distinct set of phenomena.

As is well known, the visual light of an auroral display consists for the most part of the visual green line, and accordingly it is this component (auroral green) which is most strongly reinforced when a bright display is in progress. It is always found, however, that the red and blue components are strengthened as well. The following typical examples may be given :

PLACE	DATE	RED	AURORAL	BLUE
Victoria	September 20, 1925.	+2.6	+13.5	+13.0
Kingston	March 5, 1926.	+5.9	+13.0	+13.4
Lerwick	January 13, 1926.	+2.1	+16.7	+11.9

These may be compared with the normal values in the absence of a display, given earlier in this paper. The increase of intensity in the blue part of the spectrum is probably attributable in the main to the negative bands of nitrogen.

The increase in the red is less marked. It may be due in part to the known red line of the aurora, but I believe more to an (apparently) continuous background, which may, of course, be an unresolved band spectrum.

Conclusion

In conclusion, I must emphasize that much of the work of this paper, though necessarily organised and edited from one centre, would have been impossible without the friendly and generous co-operation of the workers whose names haves already been recited. They have given their time and trouble without stint.

As regards the future, it has been borne in upon me that greater accuracy of photometric measurement is a chief requisite. This will be obtained by means of a photoelectric cell. Most of the difficulties have been overcome, and preliminary observations have been in progress for some months past. I have been able to follow the changes of intensity from hour to hour on clear nights; some evidence has been found suggesting a diurnal

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periodicity. The observed intensity nearly always increases between nightfall and midnight, beyond which the observations have not usually been carried. Although no correlation has been found in the irregular variations at distant stations, there must be correlation at stations close together, and it is important to determine limits of distance. By the photo-electric method, this should be comparatively quick and easy.

Bibliography

The work here described is discussed somewhat more fully in Proc. Roy. Soc. A., Vol. 119 p. 11, 1928.

See also on some points earlier papers

Proc. Roy. Soc. A., Vol. 106, p. 117 (1924) and

Proc. Roy. Soc. A., Vol. 109, p. 428 (1925).

The results of these earlier papers are however in part superseded.

A paper on *Visual Observations of the Aurora Line in the Night Sky* appears in " Gerland's Beitrage zur Geophysik ", May 1928.

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PROBLEMS AND FUTURE LINES OF RESEARCH ON THE AURORA POLARIS

by

Carl STÖRMER

In the Autumn, 1928, a new auroral research Observatory near Tromsö in northern Norway will begin its work, and as this will probably have much importance for future work on the aurora, some information about the Observatory may be of interest.

It has been built with a gift of about 74,000 dollars made by the Rockefeller International Education Board to Norway, for the erection of the observatory with magnetic huts, and house for the director and assistant and for the scientific equipment. To the Observatory belongs also a magnetic Bureau which will have its seat in the new geographical Institute in Bergen. The whole Institution has received the official name " The Norwegian Institute for Cosmical Physics ".

The Norwegian Government has decided to maintain the Institute with an annual budget of about 55,000 Norwegian crowns, by transferring to the new Institute the budget of the Haldde Observatory, which will be abandoned as a permanent observatory when the new Institute begins to function. The scientific work will be done in accordance with plans and instructions given by a committee of 5 members (initially Krogness, Störmer, Sœland, Vegard and the future director of the new Observatory).

This new auroral Observatory will be very well situated at the northern end of the Lake Prœstevandet at Tromsö. All the buildings will very soon be completed. The magnetic equipment will be that of a first order magnetic observatory.

The work at the Observatory will be devoted especially to all sorts of photographic work on the aurora, including photogrammetric measurements of its height and situation and studies of its spectrum. So far as time allows, other researches connected with aurora will be undertaken.

The material collected at the Observatory will be measured and calculated either there or at the magnetic Bureau in Bergen or at Oslo. Auroral science may be grateful to Professor Vegard, who took the first initiative in asking the Rockefeller International Education Board for grants to erect this Observatory.

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In order to make efficient comparison between theory and observation, it is of great interest to know what happens simultaneously all round the auroral zone ; for this purpose international cooperation is necessary. In order to facilitate this, it was decided at the 1927 meeting of the International Geophysical Union at Prague to prepare a photographic atlas of aurorae and a scheme of observation. A committee was appointed for this work, consisting of the following members :

Canada :	Sir F. STUPART ;
Denmark :	Dr. LA COUR ;
United States :	Commander HECK ;
Finland :	Dr. MELANDER ;
Great Britain :	Professor CHAPMAN ;
Norway :	Professor STÖRMER, Président.
Sweden :	Professor CARLHEIM GYLLENSKÖLD.

This winter I have selected characteristic forms from among my photographs of aurorae and for the consideration of the Committee have worked out the classification for the auroral atlas and a scheme of observations*. It will be of decided importance if photographic records of the aurora can be obtained along the Siberian coast, in Alaska, Canada, Greenland, Iceland and the Shetland Isles.

On a visit in June 1928 to the meeting in Leningrad of the International Association " Aeroarctic ", I am endeavouring to interest Russian scientists in the establishment of photographic auroral stations in northern Siberia. At the Astronomical Congress at Leiden in July, I shall speak about the plans with English and American geophysicists for establishing auroral photographic stations in Canada and Shetland. From American authorities I have already heard that there is some probability of getting such a station in Alaska.

As to the observational work and its importance I must refer to the paper entitled *Problemen und Richtungen der künftigen Erforschung des Polarlichtes*, in the Journal " Arctis ". Both theoretical and observational problems connected with aurora are discussed in this paper.

As to my own recent researches on the aurora polaris I may mention the connection between the very high aurora rays and the sunlight, published in " Nature ", 3rd September 1927.

Further, photographs of aurorae have been taken as often as possible from my network of photographic stations in southern Norway, and the number of photograms since 1922 now exceeds 500. Only a few of them have been measured and reduced, but the systematic working out of the material bas now begun, thanks to a grant from the foundation " Nansenfondet ", this spring.

May 1928.

* Cf. p. 127

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SOLAR INFLUENCES ON SOME RADIOTELEGRAPHIC PHENOMENA

by

R. A. WATSON WATT

Adequately quantitative methods of measurement, as applied to received radiotelegraphic waves,are of very recent growth. In consequence of this, there are not at present in existence satisfactory series of measurements which may be regarded as sufficiently homogeneous over a sufficient period to justify the drawing of statistical conclusions as to solar influences on radio phenomena. Nevertheless, from the measurements made in the course of development of methods of measurement, it is to be expected that suggestions of solar relations might emerge, which should be regarded as indicating directions for further investigation. Among the methods developed at the Radio Research Station of the Department of Scientific and Industrial Research, two investigations lent themselves to inspection from this point of view. These are the analysis of the wave trains received from long wave transmitting stations and the general investigation of the nature and origin of atmospherics. While no systematic comparisons have been made with the indices of solar activity in either case, certain results may be noticed under the two headings of normal diurnal and seasonal phenomena and of abnormal phenomena associated with terrestrial magnetic disturbance, here accepted as a probable symptom of solar disturbance.

In the case of the artificially generated long wave signals (1) (2), the general march of diurnal variation is that during daylight the waves are received without evidence of abnormal polarisation, and with intensities indicating a reflection coefficient from the upper conducting layer of the order of 0.10 to 0.15. No systematic diurnal variation in the reflection coefficient has been found, but more or less random drifts in value are observed to occur. Shortly before sunset the reflection coefficient begins to rise, and when the sun is 7° below the surface horizon at a point midway between transmitter and receiver, abnormal polar-

(1) Hollingworth, Journal of the Institution of Electrical Engineers. Vol. 64, May 1926.
(2) Hollingworth, Proc. Roy. Soc. A. Vol. 119 June 1928.

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isation appears abruptly and reaches a fairly steady value within some 15 minutes. The evidence is not yet sufficient to indicate whether the day-to-day variation of this abnormal polarisation is cyclic, or the way in which it is related to other geophysical phenomena. During the hours of darkness, conditions remain comparatively steady, while during the sunrise period an inverse sunset cycle occurs. The phenomena described are typical of summer conditions. A remarkably abrupt change between summer and winter conditions takes place during the first week in May and the last week of October. During the winter period the sunset and sunrise cycles are as described, but about half an hour after sunrise abnormal polarisation reappears. This may disappear within an hour or two, to return before sunset, or it may persist throughout the day. Occasionally all cycles of variation may disappear completely for some days.

In some comparatively severe magnetic storms no effects on the propagation of long wave signals have been detected. On the other hand, in one particular case of a less severe storm, there was evidence for a direct relation between the peaks of magnetic intensity variation and of polarisation of the radio wave. There is also some evidence for a cumulative effect in which prolonged periods of magnetic activity are accompanied by disturbance in radio propagation : for example, in 1927, "winter" phenomena sometimes appeared in the middle of summer, while in 1928 characteristic "summer" behaviour was occasionally observed in February and March. Recent small isolated storms have not shown any effect on long wave signals.

The investigation of atmospherics has revealed very definite solar and magnetic controls. In directional observations during 1920 coefficients of correlation between monthly mean direction of arrival of atmospherics and monthly mean solar altitude at the time of observation were found to amount to 0.93 ± 0.03 at 7 h., 0.81 ± 0.07 at 13 h., 0.92 ± 0.03 at 16 h., while the coefficients for all observations collected into one single group amount to $0.690 \pm .06$. The coefficients of correlation between mean number of atmospherics per unit time and surface temperature was found to be for all observations at the three hours above mentioned $0.420 \pm .09$ (3). In directional recording during 1922-1924 it was found that the principal stationary points in the monthly mean curves of diurnal variation of intensity of atmospheric disturbance on a long wave occurred at approximately fixed intervals before or after loca sunrise or sunset at the receiver (4). While no extensive inves-

(3) Watson Watt, Proc, Roy. Soc. A. Vol. 102, 1922.
(4) Watson Watt Journal I.E.E. Vol. 64, May 1926.

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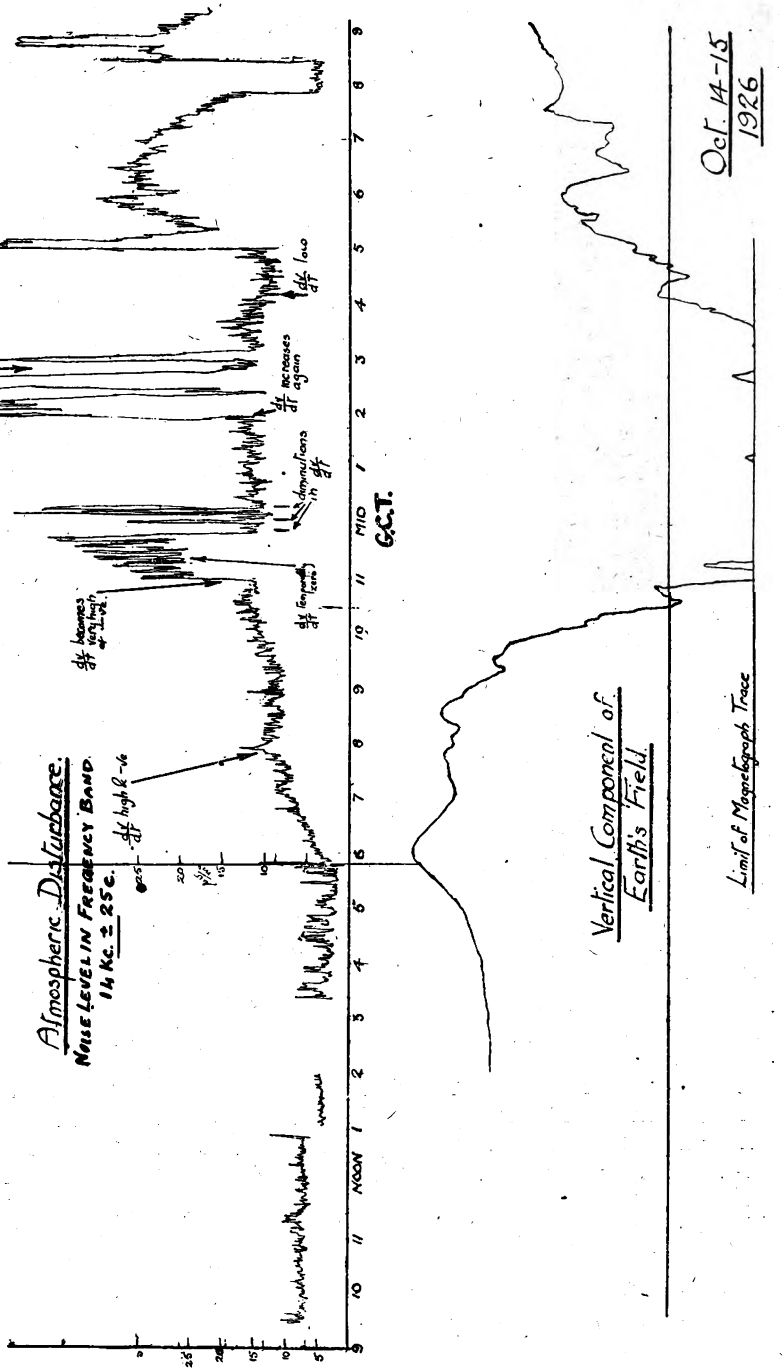

Fig. 1 — Curves showing relation of radiotélégraphic atmospherics to terrestrial magnetic disturbance. Atmospheric recorded at Radio Research Station, magnetic elements at Eskdalemuir.

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tigation has been undertaken as to correlation with Wolfer sun spot numbers or magnetic character figures, preliminary comparisons have failed to reveal any obvious relationships. On the other hand, there is very definite evidence of correlation in a comparison with magnetograms. The nature of the relation there appears to be that the atmospheric disturbance lying within a narrow frequency band centred on 14 kilocycles increases suddenly by a factor of 2 to 4 fold at moments when the rate of change of the vertical component of the earth's magnetic field reaches high values. The accompanying figure shows the general character of the recorded atmospheric disturbance during the magnetic storm of October 14th-15th 1926, and indicates the relation with rate of change of the vertical magnetic field. There is also fairly definite evidence of a 27-day interval in the occurrence of sudden changes in intensity of atmospheric disturbance of the character shown in the figure. It has not, however, been thought desirable to investigate this phenomenon until time can be found for a direct comparison between magnetograms and the available atmospheric records. It should be understood that the frequency band mentioned is not peculiar in its properties, and is merely a band arbitrarily selected for continuous recording as a sample of long-wave disturbance.

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THE PROPAGATION OF AIRWAVES TO GREAT DISTANCES: AN INDICATION OF CONDITIONS IN THE UPPER ATMOSPHERE

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1. That the sounds produced by explosions can occasionally be heard at distances of 200 kilometres or more has been known for a long while, but no serious investigation of the phenomenon was undertaken until the present century. The pioneer work was done by Von dem Borne who collected information with regard to the explosion which occured at Förde in Westphalia on December 14th. 1903. Von dem Borne established the existence of an inner and an outer zone of audibility, separated by a zone of silence. The same characteristic feature has been found in every other instance which has been the subject of investigation. As a general rule, the outer zone of audibility is only found in certain directions, it does not completely surround the source.

2. During the great war distant gunfire was heard regularly at places far from the battlefields, but circumstances were not favourable for the collection of information with regard to individual explosions. The most valuable observations during this period were of a statistical character, notably those of De Quervain in Switzerland and of Miller Christy at Chignal near Chelmsford. Christy found that the firing on the Continent was audible only during the summer months, the earliest date being April 22nd, the latest September 6th. On the other side of the battle front, at certain places it was found that gunfire was more likely to be heard in winter. It appeared that the outer zone of audibility was to the NW of the source of sound in summer and to the SE in winter. It may be however that the safer generalisation is that the zone of audibility is nearer to the origin in winter. According to Wegener, the central distance of the zone is 110 km. in January and 190 km in August. In winter Christy, being about 170 km. from the nearest battlefields, was too far away to hear the firing.

Another remarkable fact to which attention was called during the war is that at times there may be a second region of audibility at twice the distance of the ordinary outer zone. This phenomenon was noted in Germany during the siege of Verdun. An earlier instance is on record: an explosion at Wetten-Annen in 1906.

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3. At the end of the war, A. de Quervain made the suggestion that the destruction of large quantities of explosives would provide opportunities for observations of audibility. This suggestion has proved fruitful. Under the auspices of a Commission associated with the International Meteorological Committee, there have been explosions at Oldebroek in Holland and at La Courtine in France. More numerous experiments have been carried out in Germany.

The outstanding advantage of the prearranged explosions is the possibility of timing the interval between the generation of the explosion wave and its reception. This advantage is enhanced when autographic instruments can be used for recording the waves. The observations show that the times of transmission of the sound to points near the source are normal, i.e. the mean velocity calculated from the distance and the time of passage is approximately the velocity of sound in still air at the prevailing temperature. The times of transmission to the outer zone of audibility are found to be " abnormal ": the apparent mean velocity is much less than the velocity of sound in still air at the prevailing temperature.

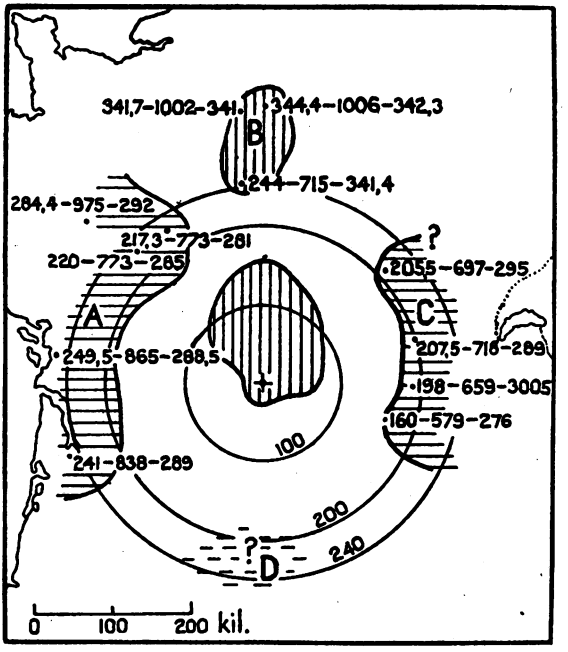

Fig. 1 — Audibility of the explosion at La Courtine May 15 1924.
The numerical data are distance in kilometres, time in seconds, and apparent velocity in metres per second

The results of the La Courtine experiments have been published in full detail by Prof. Maurain. Fig. 1 reproduced from his paper shows the distribution of audibility on May

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15th 1924. On this occasion there were regions of abnormal audibility to the east and west. In the neighbourhood of Paris, instrumental observations shewed that airwaves travelling with the normal velocity of sound could be recorded.

4. With regard to the researches which have been carried on so vigorously in Germany, an interesting general description has been published by Prof. Hergesell. A full report on this work up to the middle of 1926 is understood to be in the press and will no doubt be published before the present communication. Meanwhile the fundamental information with regard to airwaves can only be gleaned from the studies of authors who have had access to the observations.

Hergesell's paper is devoted mainly to the audibility of explosions in the literal sense. Maps of the zones of audibility are given for four experiments, two in summer and two in winter. A remarkable feature of these maps is the occurrence in three cases out of four of a series of zones of audibility at increasing distances. Thus, for the series of observations on the three days January 26-28 1926, the map shows a zone of normal audibility narrow in the west, but extending to 120 km. from the explosion in the southeast. The zone of silence is completely surrounded by the first zone of abnormal audibility, but beyond this on the west are two other regions of audibility with observations at ranges of 260 km. and 440 km. There is definite information demonstrating the inaudibility of the explosions at intervening points.

5. Great explosions in which tons of high explosives are utilised can not be arranged except under special circumstances and in England we have been developing a less expensive method of investigation.

In 1927 arrangements were made for broadcasting from Daventry the times at which the heaviest gun was being fired on the Shoeburyness range and at the same time sound-ranging apparatus (hot-wire mcrophones) was installed at Birmingham, Bristol and Southampton. The first trials shewed that the records obtained with such apparatus were much more reliable than any aural observations and that airwaves were recorded regularly when there was no audible sound. In the most recent trials four or five stations have been in operation. Up to the time of writing, there have been eight occasions on which the airwaves have been timed between Shoeburyness and Birm ngham (210 km.). These eight occasions have been in the ummer months. Unsuccessful attempts to obtain records were made in November and January, probably unsuccessful because Birmingham was not in the zone of abnormal audibility.

The aerial disturbances which are recorded are sometimes spread over several seconds and in some cases there are two or even three distinct pulses separated by intervals of two or more seconds, so that it is not always easy to give a precise

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estimate of the time of passage of the air-waves. The record which is reproduced is a particularly clear one in which the whole disturbance passed in about 1/8 second The fluctuations in the time of passage in the course of an hour or so are sometimes considerable. Thus at Birmingham on July 9th 1927, times from 11 m. 48 s. to 12 m. 0 s. were recorded. On the other hand at the same station on August 3rd 1927 there were 5 consecutive records for which the times of transmission were within 2 seconds. On July 17th 1928 eight rounds were record

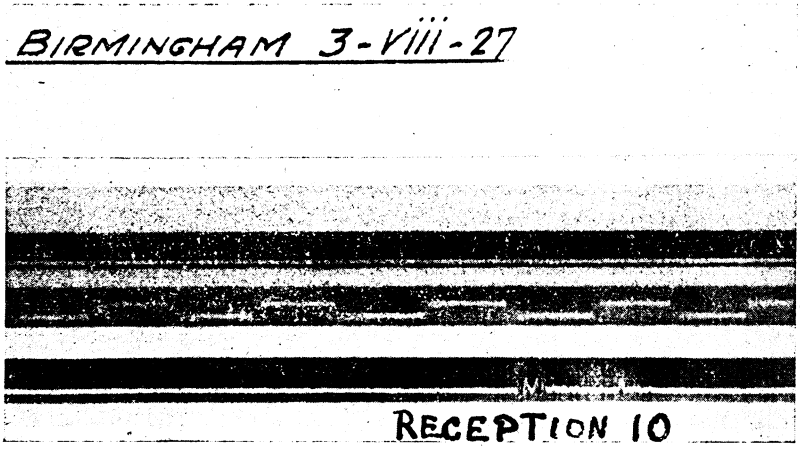

Fig. 2 — Air waves recorded by the hot-wire microphone at 210 km.

ed at Bristol and the computed time of transit over 228 km. did not vary by more than 1/2 sec. from the mean, 12 m. 50 s. Such consistency implies unexpected steadiness in the atmospheric conditions as well as good work on the part of the two operators, whose " personal equations " are involved.

As the following Table shews* there is some indication of a regular annual variation in the time of passage of the air-

		MAY		JULY				AUGUST	
		11 1928	23 1928	4 1928	9 1927	13 1927	17 1928	2 1928	3 1927
		sec	sec	sec	sec	sec	sec	sec	sec
Birmingham	210 km. 11 min+	72	66	67	51	76	61	65	62
Bristol	228 km. 12 min+	57	52	—	—	—	50	55	54
Sheffield	259 km. 14 min+	—	35	33	—	—	30	—	—

* Most of the results are published here for the first time. I am very deeply indebted to Prof. S.W.J. Smith of Birmingham, Mr. M.G. Bennet of Bristol, Mr. M.H. Evans, of Sheffield and to many other collaborators who have devoted time, skill and patience to the investigation.

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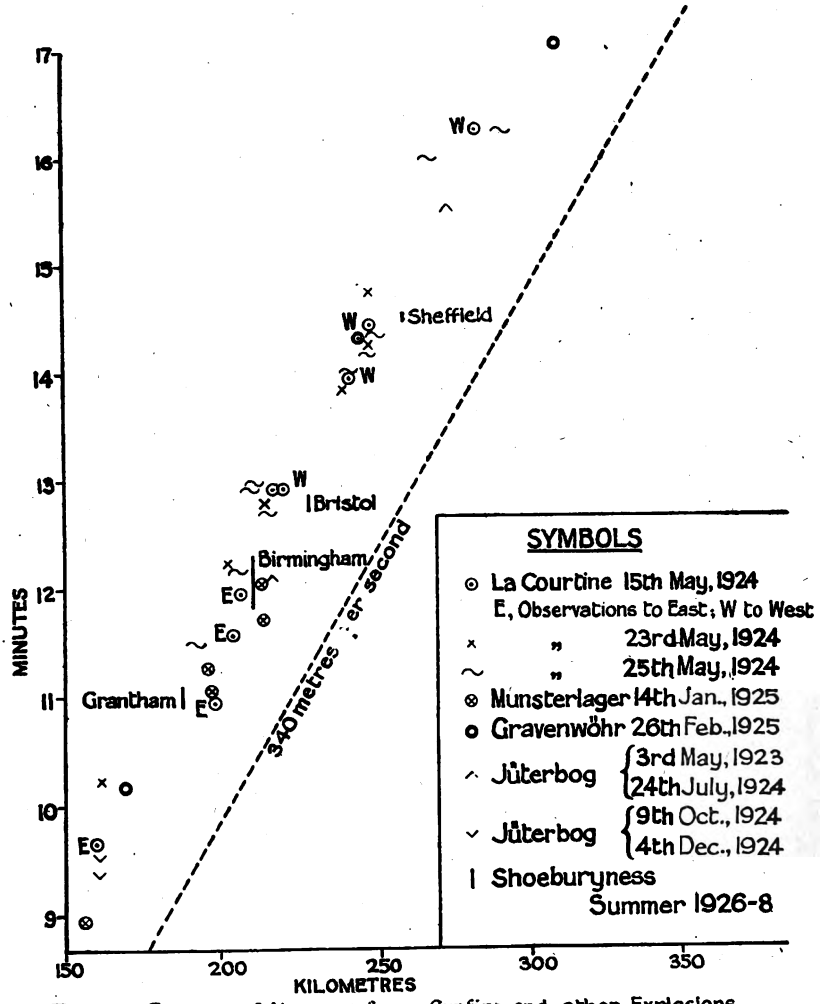
waves. The Birmingham records shew much more diffuse waves than the Bristol ones and it is therefore not surprising that the phenomenon is better developed at Bristol.

Attempts to obtain records at Southampton (153 km.) and at Exeter (294 km.) have not been successful. It appears that during the summer Southampton is within the zone of abnormal audibility. Whether waves of slight intensity reach Exeter is uncertain.



Times of Passage of Airwaves from Gunfire and other Explosions.

The vertical lines refer to observations of gunfire at Shoeburyness. The other marks refer to observations of explosions at La Courtine and in Germany.

In the trials which have taken place during 1928 arrangements have been made for determining the angles of descent of the air-waves. Two microphones are set up about 300 metres

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apart and if the interval between the times of arrival of the wave at the two microphones can be read to the hundredth of a second the angle required can be computed.* The observations obtained so far indicate that the waves which reach Bristol come down at an angle of about 20° whilst at Birmingham the rays are nearly horizontal. There are however considerable difficulties to be overcome in these experiments. The aerial disturbances change their character so much in passing over the 300 metres, that corresponding points of the films can not always be picked out.

6. In 1925 Angenheister published† a diagram shewing the relation between time and distance for the observations of abnormal audibility then available. In copying this diagram I have introduced Maurain's time for the third La Courtine explosion. I have also incorporated the observations of the air-waves from the Shoeburyness gun, my own aural observations § at Grantham and the instrumental results at Birmingham, Bristol and Sheffield. It will be seen that there is general agreement, but that the times recorded at Bristol and Sheffield are less than those given for like ranges for the audible disturbances due to the La Courtine explosions.

No observations in a secred zone of abnormal audibility are included in the Angenheister diagram. In Maurain's report there are two groups of observations which appear to fall in this category, though that author regards them as doubtful. On May 23rd 1924 the reports of three observers near Commercy at 416 km. gave the time of passage as 26 m. 1 s. On May 25th ear observations and autographic records at Cherbourg (516 km.) agree in giving 27 m. 45 s. for the time.

A diagram like fig. 3 shews the general consistency of the observations. For the comparison of the observations on different occasions, it is convenient to plot the displacements of the representative points from the line of constant velocity 340 m/s., that, being the velocity of sound in air at 15° C. In other words, we plot the difference between the observed time of passage of the sound and the time which would have been taken, had the wave travelled along the ground at 340 m/s. In fig. 4 the data for six occasions, on each of which at least three observing stations were available, are exhibited in this way. The graphs are nearly horizontal. This indicates that on any particular occasion the retardation of the sound is to a first approximation the same for all points in the zone of abnormal audibility. Four of the graphs are curved downwards,

* The first successful experiments of this character were made by O. Meisser. Zs. für Geophysik, 3 (1927) p. 285. Meisser used the undograph designed by Prof, Kuhl. The advantage of this instrument. in which the movements of a mica vane are recorded, is that the increases and decreases of air pressure can be distinguished.

† *Zs. für Geophysik, 1, (1925) p. 322.

§ Meteorological Magazine 61 (1927) p. 164.

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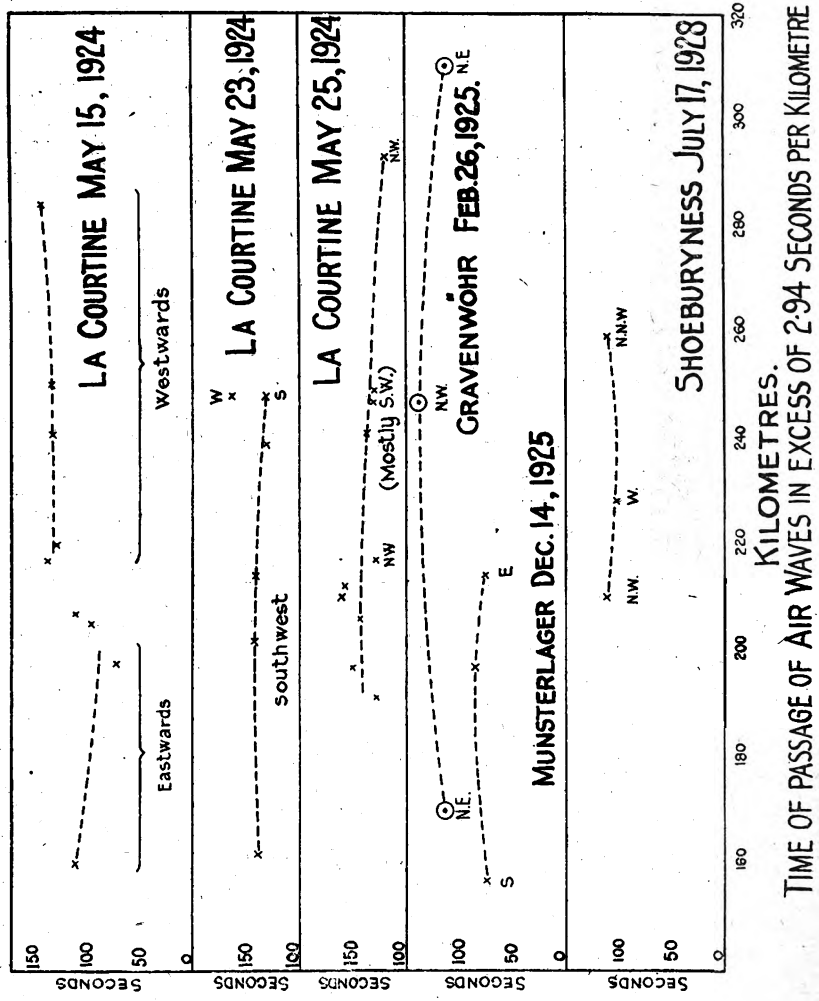

Fig. 4

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indicating that in these cases the velocity of the trace of the air-wave on the ground increased at greater distances, but the other two examples are not concordant.

On the last of these the observations are those given for July 17th in the preceding table. The range from Shoeburyness gun to Sheffield is only 31 km greater than that to Bristol, but the difference in the times of passage of the air waves is 100 seconds; at 340 metres per second, the difference would have been 91 seconds. No doubt, the explanation is to be found in the difference between the bearings of the stations from the gun.

7. In considering the significance of abnormal audibility, we note in the first place that the delay in the passage of the sound to points in the outer zone of audibility is evidence that the energy has not passed by the direct route through the lower atmosphere. On the other hand, the recorded times are not great enough to admit Von dem Borne's hypothesis that the waves have penetrated to heights at which the atmosphere might be supposed to consist mainly of light gas, hydrogen or helium. Moreover, the velocity of a sound wave at the highest point of the trajectory can be determined from the observations, for it can be shewn that this velocity is the same as the apparent velocity of the sound between neighbouring points on the ground with the same bearing from the source. This velocity is determined most readily from observations such as the recent ones at Birmingham and Bristol. These indicate that the air-waves which reached Birmingham returned to earth from a height at which their velocity was nearly the same as over the ground, whilst the waves which reached Bristol had been up to a level at which their velocity was greater by about six per cent.

It might be thought that the high velocity of the waves was due to wind. This explanation appears to be ruled out by the remarkable symmetry of the zone of abnormal audibility; the zone has been found in some cases to be nearly circular. We must conclude that the high velocity is characteristic of the air at a certain distance above the ground.

If we may ignore the wind, the estimation of the height of the apex of the trajectory of the air-waves is a comparatively simple matter. We know that the temperature of the air decreases almost uniformly from the ground up to the tropopause (the boundary between troposphere and stratosphere); in the stratosphere temperature is almost uniform. Thus uniformity persists to some level beyond 20 km. How the uniformity is interrupted we do not know, but the simplest assumption to make is that there is some definite level beyond which temperature increases at a constant rate. Thus there are two unknowns to be calculated: the height at which temperature begins to increase and the rate at which it increases. For a sound-ray which comes down at a known inclination we have

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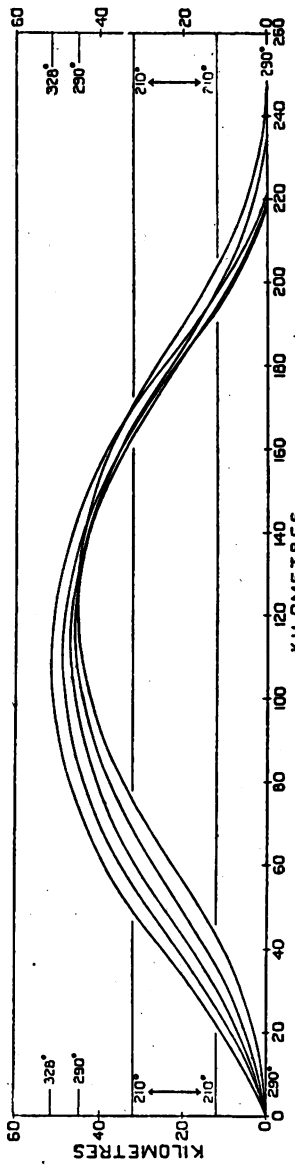

Fig. 5 Soundrays passing through an upper warm region.

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two data: the range and the time of passage, and from these two unknowns can be found. On the given assumptions a sound-ray follows an inverted cycloid in the troposphere, straight lines in the stratosphere and a cycloid in the upper warm regions. As an example we consider the conditions on May 11th 1928, when the temperature near the ground was 285,8°A, the height of the tropopause was estimated as 11 km. and the temperature there 218°A. The time of passage of the air-waves to Birmingham (210 km.) was 12 min. 12 sec., the time to Bristol (228 km.) was 12 min. 57 sec. The inclination of the trajectory at Birmingham was small, we take it as 0°; the inclination at Bristol was reckoned to be 23°50′. Interpreting the Birmingham data according to our hypothesis, we find that the uniform temperature of the stratosphere persisted to 35 km. and that the temperature 285.8°A was reached at 40 km. According to the Bristol data, the stratosphere temperature persisted to 27 km., the temperature 285.8°A was reached at 40 km. and the apex of the trajectory with a temperature of 340° A was at 51 km. The two determinations of the height at which the ground temperature recurred are in good agreement though the estimates of the height at which the transition began differ considerably.

Our method has the advantage of depending only on the observations on a particular occasion. How far this advantage is discounted by the simplifiying assumptions remains to be seen.

The results may be compared with those derived by Gutenberg in 1926 from a discussion* of the data from the earlier observations of experimental explosions :

Height in km....	0	5	10-35	40	50	60	70	80
Vely m/sec.	337	315	294	340	360	380	400	(420)
Abs. Temp.*	283	244	217	288	322	358	400	

When dealing with such a variable phenomenon as abnormal audibility, pooling all the observations has obvious drawbacks, and Gutenberg himself points out that the evidence that the sound waves actually reach heights exceeding 60 km. is not at all strong.

8. When the structure of the atmosphere can be specified, the sound-rays which start at different inclinations can be drawn. Fig. 5 shews such rays under conditions selected as appropriate for some of the observations of the La Courtine explosion of May 15th 1924. It will be noticed that some of the rays cross so that near the minimum range the sound may be

*Zs. für Geophysik, **2**, p. 105.

In a later paper (Met. Zs. 43, p. 429), Gutenberg quotes 370, 390, 410 m/sec. as the velocities at 50, 60 and 70 km. The temperatures given above I have deduced from the velocities by assuming a uniform composition for the atmosphere.

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heard twice. Actually the records of air-waves shew cases in which the disturbance is duplicated (or even triplicated) and it is hoped that it will be possible to determine the inclinations with which the individual waves arrive.

My diagram omits one important feature of a similar one published by Gutenberg. Adopting a suggestion of Wegener's, Gutenberg explains the occasional occurrence of a second zone of abnormal audibility as due to air-waves which have come down nearly to the ground and have been refracted up again, to return to earth at double the usual range. For this to happen the temperature near the ground at the intermediate point must be higher than that at the source and at the point where the sound is heard. There is some evidence that this condition is actually satisfied.

9. In 1922, about the time when the observations of the propagation of sound from explosions were being organized, Lindemann and Dobson published their theory of meteors and shewed that the air from 60 km. to 100 km. above the earth must be denser than had been supposed hitherto. The layer on which this dense air rests must be distended and therefore at a high temperature. In their original exposition Lindemann and Dobson were content to give 300°A as the temperature at 60 km. and upwards, but it appears* that their data are in better accordance with a stratification in which the rise from the uniform temperature of the stratosphere begins at about 30 km. and persists to about 50 km., at which level 380°A is reached. Lindemann and Dobson also gave the probable explanation of the high temperature of this upper region, the selective absorption and radiation by ozone. The analysis of the observations of air-waves has provided a remarkable confirmation of the meteor theory.

10. As to the future progress of the investigation, the first need is for its extension to other parts of the world. Up to the present experiments have been confined to North-West Europe. That the empyrean (as L.F. Richardson calls the upper hot layer) exists over the tropics may be deduced from old observations of "abnormal" audibility of explosive eruptions of Cotapaxi, but we have no information as to the height of the layer.

In Europe we require regular observations which will shew eventually how the height and temperature of the empyrean are related to other variables such as the amount of ozone in the upper atmosphere. The nature of the annual variation has to be determined and also the variation in the sunspot cycle. For such purposes frequent experiments in which the air-waves can be registered by instruments will be more fruitful than

*"Nature", 118 (1926), p. 312.

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occasional discharges of large quantities of explosives. I hope that some economical and efficient method of generating air-waves will be developed, so that the experiments may be conducted at a moderate cost. On the theoretical side a method of dealing with a large number of simultaneous observations and deducing not only the temperatures at various heights, but also the windspeeds, is required. It is the necessity of allowing for the existence of wind that makes the precise interpretation of the observations difficult. It is only by the cooperation of numerous workers that the difficulty will be overcome.

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SCHEME FOR OBSERVATIONS OF POLAR LIGHTS*

The method which gives the most complete and exact results is the photographic one, and this method should be used if there is any possibility of doing so.

According to different circumstances and the assistance available for the work, various alternatives may be adopted for the scheme of observations.

The following requirements are common to all alternatives :

The time for each observation should be observed as exactly as possible, at least to the nearest minute. The time should be reckoned in Greenwich mean time from 0 h. to 24 h., 0 h. at midnight.

The watch should be compared with exact time (chronometer or radio signals) in order to know how much it goes too fast or too slow and how much it gains or loses in 24 hours, and the observations should be correspondingly corrected.

The situation of the observation station should be given in latitude and longitude as accurately as possible, or should be marked on a large scale chart. The station should have a free view in all directions.

The cloudiness and the phase of the moon should be noted during the observations.

Before passing to the scheme of observations of polar light, it may be useful to point out what is the aim of such observations.

Their first use will be to obtain a statistical survey of the frequency of aurora and of its different forms as functions of time and of geographical position. But of much more importance for the explanation of the nature of polar lights is a close study of the development of single phenomena from a network of photographic stations, in order to obtain exact information of its geographical position and situation in the atmosphere.

Corresponding to these different aims and to the resources and the number of observers at the stations, the following alternatives may be indicated :

ALTERNATIVE Nº 1

Station with a single observer and without photographic apparatus.

At fixed observation hours the forms of the aurora should be noted corresponding to the photographic atlas. The situation in the sky may to a first approximation be fixed by dividing the sky into regions, S., W., N., E., consisting of the southern,

*Cf. pp. 5, 105.

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western, northern and eastern part, from the horizon up to the elevation of 60°, and Z., consisting of the region around the zenith down to 60° elevation. A better approximation is to note the stars or constellations where the aurora is situated, or to make a sketch of the position of the aurora on a simple star map. The quiet homogenous arcs should be observed separately by giving the position of the lower border or, if the arc passes in the neighbourhood of the zenith, of both borders, from one horizon to the other. It is then convenient to measure the height and azimuth of a point at one end of the lower border, of a point where the height is greatest and of a point near the other end. If the arc has not a symmetrical and regular shape, it is desirable to measure two more points between these. The measurements should be taken successively, for instance, from west to east and back again several times, in order to obtain the motion of the arc as a whole, in the direction normal to its extension.

The lower border of the arc can also be sketched on a star map.

In the case of pulsating arcs, or of pulsating surfaces, the period in seconds of the pulsation should also be observed as well as the situation in the sky.

In the case of a corona, the point of radiation should be observed at short intervals and its height and azimuth noted, or its position marked on a star map; of special interest is the most southern position of the lower border of the aurora during the time of observations. It should be carefully measured.

To measure the height and azimuth of aurora, a simple theodolite should be made, by means of which the height and azimuth can rapidly be measured, by setting on any point of the aurora and reading the two angles, correct at least to one degree.

As to the hours of observation, it would be of very great interest if they could be chosen everywhere at Greenwich mean time, for instance, during the time from 5 minutes before to 5 minutes after each exact hour.

It should be remembered that the fact that no aurora can be seen when the sky is clear is an observation of just as much interest as the other observations.

ALTERNATIVE N° 2

Station with two or more observers, but without photographic apparatus.

The programme sketched under Alternative n° 1 can now be more conveniently realised, one of the men observing and the second writing down what he says and observing the time of each observation. It is advantageous if the second man is a stenographist. Besides observations during the fixed periods mentioned under Alternative n° 1, observations may also possibly

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be made between these periods. The best would be that the observations should be made without interruption, at least on certain fixed international days. For rays and curtains, the position of the foot and lower border may be observed and, if possible, for especially marked rays, the positions of foot and summit simultaneously.

It is further very important to observe the exact time when the following changes take place :

a) When a quiet homogeneous arc dissolves in rays ;

b) When rays and curtains fade and change into diffuse quiet forms.

c) When pulsating forms appear and end ;

d) When flames towards the zenith begin and end ;

e) When a quiet homogeneous arc reappears.

The comparison of these facts from stations round the northern auroral zone, and in the Antarctic, will be of much theoretical interest.

Among other observations may be noted observations of position and distance between arcs, if several appear at the same time, and observations of position and motion of the connecting link between two parallel homogeneous arcs, in case this can be observed. Observations of high violet auroral rays after sunset or before dawn are of special interest, these rays being probably situated in the sunlit atmosphere. Notes on colours, intensities and motions of the aurora should also be made so far as time allows.

It should be remembered that very often, though an auroral display seems to have finished, soon afterwards it may begin again, so that the observers should take care not to finish their work too early.

ALTERNATIVE Nº 3

Station with one observer and a photographic apparatus.

If the observer has at his disposal a camera with the necessary equipment to photograph the aurora, much more important results can be obtained. The position of the aurora among the stars can be found quite exactly by photographing it and by observing the time when each photograph is taken (with an accuracy of at least half a minute). The number of plates available should be sufficient to enable photographs to be taken as often as is needed. With a camera of the kind used at the Haldde Observatory in Norway six photographs can be taken on each plate (size of plate 9 ×12 centimeters), and for one night a collection of two dozen plates in their plate holders is in general more than sufficient.

It is of special interest to photograph homogeneous quiet arcs after the same principle as the observations mentioned under the foregoing alternatives, and also to determine the point of radiation photographically. For each photograph the

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stars or constellation towards which the camera is pointed should be noted along with the exact time of the photograph.

If time allows, each interesting form of aurora should be photographed.

In general the same remarks as under the foregoing alternatives apply to this alternative, but it is to be remembered that the results obtained by photography are much more important than those obtained visually, so that more care should be devoted to the photographic work.

ALTERNATIVE Nº 4

Station with two or more observers and a photographic apparatus.

In this case one of the observers should take photographs and dictate all the necessary observations to the second one who writes down what is said, and notes the exact time of the photographic exposure by observing an illuminated watch. If possible he stenographs his notes. See also Alternative nº 2.

ALTERNATIVE Nº 5

A pair of photographic stations connected by telephone in order to take photograph of the aurora.

If such a pair of stations is established, results of the greatest scientific interest may be obtained by finding the exact height and situation of the aurora in the atmosphere. For this case a more detailed report on equipment and programme will be published elsewhere.

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INDEX OF MEMORANDA

ABETTI G. — On the Connection between Solar Eruptions and Terrestrial Magnetic Storms 9

ABBOT, C. G. — Variations of Solar Radiation 14

APPLETON, E. V. — Solar Activity and Wireless Transmission. Some Theoretical Considerations 16

AUSTIN, L. W. — Solar Activity and Radio Transmission 18

BABCOCK, H. D. — Progress on the Study of the Green Auroral Line λ 5577.350 27

BUREAU, R. — Le rôle respectif de la très haute et de la basse atmosphère dans la propagation des ondes radio-électriques..... 29

CHAPMAN, S. — The Solar and Lunar Diurnal Magnetic Variations.... 35

CHREE, C. — Recent work on Terrestrial Magnetism and Electricity... 39

DESLANDRES H. — Sur les Relations entre le Soleil et la Terre..... 41

DOBSON, G. M. B. — Measurements of the Amount of Ozone in the Upper Atmosphere 44

FABRY, Ch. — Travaux récemment faits en France sur l'Absorption des Radiations par l'Ozone contenu dans la haute Atmosphère..... 49

FERRIE, G. et JOUAUST, R. — L'étude des relations entre les Manifestations de l'Activité solaire et la Propagation des Ondes radiotélégraphiques 55

GÖTZ, F. W. Paul. — Zur Ozonmangel der tieferen Atmosphärenschichten 60

GOWAN, E. H. — The Effect of Ozone on the Temperature of the Upper Atmosphère 62

GREAVES, W. M. H. — Discussion of the Greenwich Solar und Magnetic Data 66

GUNN, ROSS. — The Diamagnetic Layer in the Earth's Atmosphere and its Relation to the Diurnal Variation of Terrestrial Magnetism..... 69

GUTTON, C., et GUTTON, H. — Sur les Propriétés Dielectriques des Gaz Ionisés et la Propagation des Ondes Electromagnétiques autour de la Terre 70

HULBURT, E. O. — Ionisation in the Upper Atmosphere of the Earth. 80

— On the origin of the Aurora Boreales..... 82

JOUAUST, R.: see Ferrié.

MAURAIN, Ch. — Sur la Recherche des Relations entre les Perturbations magnétiques et l'activité solaire 83

MEISSNER, A. — Problème der Ausbreitung der Radio Wellen 86

PETTIT, Edison. — Measurements of Ultra-Violet Solar Radiation 1924-28 90

PICKARD, G. W., Some Correlations of Radio Reception with Atmospheric Temperature and Pressure 94

RAYLEIGH, Lord.— Some Recent Work on the Light of the Night Sky. 96

STÖRMER, Carl. — Problems and Future Lines of Research on the Aurora Polaris 108

WATSON WATT, R. A. — Solar Influences of some Radio-telegraphic Phenomena 110

WHIPPLE, F. J. W. The Propagation of Airwaves to great distances; and indication of conditions in the upper atmosphere..... 114

Scheme for observations of Polar Lights..... 127

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International Research Council

THIRD REPORT OF THE COMMISSION APPOINTED TO FURTHER THE STUDY OF

SOLAR AND TERRESTRIAL RELATIONSHIPS

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Conseil International de Recherches

TROISIÈME RAPPORT DE LA COMMISSION INSTITUÉE POUR POURSUIVRE L'ÉTUDE DES

RELATIONS ENTRE LES PHÉNOMÈNES SOLAIRES ET TERRESTRES

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THIRD REPORT
of the Commission appointed to further the study of

SOLAR AND TERRESTRIAL RELATIONSHIPS

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3e RAPPORT
de la Commission instituée pour poursuivre l'étude des

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INDEX OF MEMORANDA.

ABBOT, C.G.	Report on Solar and Terrestrial Relationships	4
ABETTI, G.	On Ultra-Violet Radiation	5
ABETTI, G.	On the meaning of the Character Figures of Solar Activity	6
AUSTIN, L.W.	Solar Activity and Radiotelegraphy	10
BERNHEIMER, W.E.	Ultraviolet Solar Radiation and its Relation to the Solar Constant. Solar Activity, the Ozone Content and the Turbidity of the Earth's Atmosphere	16
BROWN, H.C.	Night Radio Receptivity Measurements Parallel to the Magnetic Meridian	21
BRUNNER, W.	On the Character Figures for Solar Phenomena	22
BUREAU, R.	Les Parasites Atmosphériques et l'Influence Solaire	25
CHAPMAN, S.	Solar Influences on the Earth's Magnetism and on the Upper Atmosphere	29
CLAYTON, H.H.	Relation of World Weather to Solar Radiation Changes	31
D'AZAMBUJA, L.	Sur l'Observation des Phénomènes Éruptifs dans la Chromosphère Solaire et leurs Relations avec les Orages Magnétiques	37
DESLANDRES, H.	Relations entre le Soleil et la Terre	41
DOBSON, G.M.B.	Report on Measurements of Atmospheric Ozone	42
DOUGLASS, A.E.	Tree Growth and Solar Cycles	45
FABRY, CH.	Sur les Methodes pour l'Étude des Variations du Rayonnement Solaire	48
FISK, HARLAN W.	Magnetic Secular-Variation and Solar Activity	52
FLEMING, J.A.	Researches of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington bearing on Solar Activity and the Earth's Magnetic and Electric Fields	60
GÖTZ, F.W.P. und LADENBURG, R.	Zur Ozonfrage der tieferen Atmosphärenschichten	65
GOWAN, E.H.	Note on the Temperature of the Upper Atmosphere	66
GREAVES, W.M.H.	Discussion of the Greenwich Solar and Magnetic Data	68
GUNN, Ross	Review of Certain Contributions to Solar and Terrestrial Magnetism	70
GUTTON, C. et GUTTON, H.	Sur les Propriétés des Gas Ionisés et la Propagation des Ondes Radiotélégraphiques dans la Haute Atmosphère	73
HALE, G.E.	Cooperative Research with the Spectro-helioscope	78
HARANG, Leiv.	Memorandum on Investigations on Aurora at Nordlysobservatoriet, (Auroral Observatory) Tromsö	80
HULBURT, E.O.	The Ultra-Violet Light Theory of Aurorae and Magnetic Storms	81
KOSTITZIN, V.A.	On the Relation of Magnetic Agitation to Solar Activity	82
LABROUSTE, M. et Mme.H.	Composantes Périodiques de l'Activité Solaire et Composantes Correspondantes dans le Magnétisme Terrestre	86
McLENNAN, J.C.	On the Auroral Green Line	90
MENZEL, D.H.	Auroral Phenomena and the Solar Chromosphere	99
MOORE, Charlotte.	Quantitative Determination of Physical Conditions existing in Sun-spots	100
NICHOLSON, S.B.	Solar Character-Figures	103
PETTIT, E. and NICHOLSON, S.B.	The Temperature of Sun-spots from Radiation Measurements	103

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PETTIT, E.	Ultra-Violet Solar Radiation during the period 1924-1931	105
QUÄCK, E.	Untersuchungen zur Aufklärung der Übertragungsverhältnisse bei Kurzwellen	106
RAYLEIGH, Lord.	The Light of the Night Sky and its Annual and Long Period Variations	111
STETSON, H.T.	The Correlation of Solar and Lunar Phenomena with the Ionization of the Earth's Atmosphere	114
ST. JOHN, C.E.	Variability of Solar Rotation	116
STÖRMER, C.	Auroral Research	123
WHIPPLE, F.J.W.	The Study of the Propagation of Airwaves to Great Distances: Progress since 1928.	124
WULF, O.R. and MELVIN, E.H.	The Effect of Temperature upon the Ultra-violet Absorption Spectrum of Ozone	131

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N O T I C E.

The Committee was first appointed provisionally by the Executive Committee of the International Research Council in June, 1924, and confirmed by the Council in July, 1925; its membership, during the whole or part of the period from the date of re-appointment, 1929 January 1, to July, 1931, was

ABBOT, C. G.
ABETTI, G.
BAUER, L. A.
CHAPMAN, S. (Chairman)
DESLANDRES, H.
FERRIÉ, G.
SIMPSON, G.C.
ST. JOHN, C.E.
STÖRMER, C.

together with

FLEMING, J.A.

G. Abetti and C. E. St. John were appointed on the nomination of the International Astronomical Union. G. Ferrié was appointed on the nomination of the International Union for Scientific Radiotelegraphy. L. A. Bauer was appointed on the nomination of the Union for Geodesy and Geophysics (Section of Terrestrial Magnetism and Electricity). He resigned in 1930 owing to ill-health. G. C. Simpson was appointed on the nomination of the International Union for Geodesy and Geophysics (Section of Meteorology). J. A. Fleming was co-opted in 1930 in succession to L. A. Bauer, in consultation with the Executive Committee of the Association of Terrestrial Magnetism and Electricity, of the International Union for Geodesy and Geophysics.

On July 12, 1931, the International Research Council reappointed the existing Committee to serve until December 1934, and also appointed the following three new members, to serve from July 1931 to December 1934.

APPLETON, E.V.
BRUNNER, W.
FABRY, C.

The Committee have chosen G. ABETTI to be Chairman from January 1932, on the termination of the period of office of the present Chairman.

The Committeepresented previous Reports to the International Research Council in July 1925 and July 1928; these were published and circulated in 1926 and 1929. A few copies of these reports are still available.

From January 1932 onwards, correspondence relating to the work of the Committee should be addressed to Dr. G. Abetti, R. Osservatorio Astrofisico, Arcetri-Firenze (3R) Italy. Requests for copies of the first three reports of the Committee should be addressed to Professor S. Chapman, Imperial College of Science and Technology, South Kensington, London, S.W.7.

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THIRD REPORT

TO THE

INTERNATIONAL RESEARCH COUNCIL.

1. Publication of the Second Report.

The Second Report of the Committee, presented to the Council in July, 1928, was published in book form in 1929; it included a number of memoranda, by various authors, on different branches of science coming within the scope of the Committee.

It also included (i) the report of the Sub-Committee of the Solar Physics Commission of the International Astronomical Union, appointed to prepare a scheme for the assignment of solar character figures to each Greenwich day; and (ii) a Scheme for Observation of Polar Lights, drawn up by a Sub-Committee of the Section of Terrestrial Magnetism and Electricity of the International Union for Geodesy and Geophysics. Seven hundred and fifty copies of the Second Report were printed through the grant made by the Council to the Committee for this purpose. The majority of these were distributed to scientific Libraries, Institutions and individual investigators; the distribution was made in co-operation with, and partly by, the Secretaries of the International Unions of Astronomy, Geodesy and Geophysics, and Radio-telegraphy.

2. The Constitution of the Committee.

Since the International Research Council reappointed the Committee (for the period 1929 January 1 to 1931 December 31) in July 1928, the Committee has lost two members, C. Chree and L. A. Bauer. Dr. Chree was first appointed in October 1924, at the request of the Section of Terrestrial Magnetism and Electricity of the International Union for Geodesy and Geophysics; he died in August 1928. Dr. Bauer was first appointed in July 1928, as representative of the same body; he resigned in 1930 owing to ill-health. The Committee co-opted Dr. J. A. Fleming as his successor, after consultation with the Executive Committee of the Section.

In accordance with the Regulations for the constitution of the Committee, adopted by the Council in the form recommended by the Committee in their Second Report*, the following bodies have been invited to name representatives/ for appointment to the Committee by the International Research Council/, should the Council see fit to continue the Committee. The representatives so named are indicated in each case.

The International Astronomical Union (2):
G. ABETTI and C. E. ST. JOHN.
The International Union for Radio Telegraphy (1):
General FERRIÉ.
The International Union for Geodesy and Geophysics.
(a) The Association for Meteorology (1):
G. C. SIMPSON.
(b) The Association for Terrestrial Magnetism and Electricity (1):
J. A. FLEMING.

3. Bulletins of Daily Character Figures for Solar Phenomena.

In its First Report the Committee recommended that the International Astronomical Union be asked to organize a scheme for the characterization of successive Greenwich days according to the

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* (p.2, Sections I-V). / To the number indicated in brackets.
/ For the period 1932 January 1 to 1934 December 31.

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state of the sun with respect to one or more of its variables. In their Second Report the Committee reported the favourable response of the International Astronomical Union to this request; the Solar Physics Commission of the Union had appointed a sub-committee (President, G. Abetti) to organize the preparation of a quarterly bulletin giving daily character figures for five separate solar phenomena - sunspots, calcium flocculi, Bright $H\alpha$ -flocculi, dark $H\alpha$ -flocculi, and ultra-violet solar radiation.

These bulletins have been issued quarterly for the period from 1928 January 1 onwards. The cost has been met by annual grants made for this purpose by the International Research Council, on the recommendation of the present Committee in their Second Report (p.7): these grants, originally made for three years, were extended by the Council for a fourth year, to cover the year 1931. The bulletins are prepared and published by the Federal Observatory, Zürich, under the supervision of Professor W. Brunner. For the year 1928 the character figures referred to the state of the sun's surface between two meridians 30° on either side of the central meridian; in addition the bulletins gave the relative daily sunspot number for the whole disc, as assigned at the Zürich Observatory according to the plan instituted and carried on by Wolf, Wolfer and Brunner. From 1929 January 1 the bulletins have given similar character figures for a limited area of the disc and also for the whole disc; moreover the limited area was modified, so as to be bounded by a central circle of half the diameter of the whole disc.

These bulletins have been issued to a large number of institutions and individual investigators, according to a list drawn up in co-operation with the International Unions of Astronomy, Geodesy and Geophysics, and Radio-Telegraphy. They seem likely to be of much service in the investigation of solar and terrestrial relationships.

The sub-committee which has organized the preparation of the bulletins considers that data are available, in the archives of solar observatories, for the assignment of similar character figures for several years prior to 1928; they consider it desirable to extend the series of daily solar character figures in this way, and Dr. Brunner is willing to undertake the collection and coordination of the data from 1913 onwards, if financial provision for its publication can be obtained. The International Astronomical Union has made a grant of seventy-five pounds sterling towards the publication.

The Committee consider that the proposed extension of the daily solar data is very desirable, and they recommend that the International Research Council make a grant of seventy-five pounds sterling for the purpose.

The Committee also recommend that annual grants, each not exceeding forty pounds sterling, be continued to the Federal Observatory, Zürich, for the three years 1932 to 1934 inclusive, for the publication of quarterly bulletins of solar daily character figures for these years.

4. The Proposed New International Polar Year, 1932-3.

The Committee are glad to note the active plans now being made for a repetition and extension in 1932-3 of the scheme of simultaneous observations, especially in polar regions, which was carried on in the international polar year of 1882-3; the Second Polar Year is to extend from August 1932 to August 1933, both months included. The programme includes the establishment of a number of observing posts in polar regions, and extended observations at existing observatories in lower latitudes. The problems to be investigated are terrestrial magnetism and atmospheric electricity, meteorology especially with reference to the upper atmosphere, and

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the aurora. The preparations are being directed by the International Commission for the Polar Year 1932-33, under the Presidency of Dr. la Cour, and the General Assembly of the International Union for Geodesy and Geophysics at their meeting in Stockholm appointed a Committee to co-operate with the Commission. The importance of such work, particularly in regard to terrestrial magnetism and aurorae, was stressed in the First Report of the Committee (p.10), and the Committee feel confident that the project of the Polar Year will receive full support from the International Research Council.

5. Daily magnetic character figures.

The Association of Terrestrial Magnetism and Electricity at Stockholm in 1930 adopted a new scheme for the assignment of daily magnetic character figures, to be tried for a period of three years alongside the scheme that has been in successful operation for many years. The new daily figures, which depend in a definite way on the daily ranges of the magnetic elements, will be issued from De Bilt together with the character figures calculated as heretofore.

The Committee in their Second Report referred to the desirability of supplementing the international daily character figures for magnetic disturbance by daily figures relating to the amplitude of the part of the daily magnetic variation which is of quiet-day type. This part appears to be a separate phenomenon that varies independently of the degree of magnetic disturbance.

It would at present be premature to formulate a definite scheme for the daily figures suggested, but work preparatory to such formulation has been in progress* since 1928, and will be continued.

6. Memoranda on recent progress.

Attached to the present Report there are numerous memoranda, contributed by members of the Committee and by other investigators at their request, which describe recent work on various aspects of solar and terrestrial relationships. While the Committee do not hold themselves collectively responsible for the opinions and conclusions expressed in these memoranda, which in some cases necessarily deal with controversial matters, they regard the memoranda as evidence of fruitful activity during the past few years in many subjects bearing on solar and terrestrial relationships. On account of the wide variety of these investigations, and the desirability that information as to work in cognate branches should be made readily accessible to workers in these fields, the Committee recommend the publication and distribution of the memoranda with this Report.

7. Ultra-violet solar radiation.

The Committee consider it desirable that further investigations of the solar spectrum in the ultraviolet region be made with the aim of determining more accurately than heretofore how far the variations of this radiation, as received at ground level, are due to terrestrial causes, such as changes in the amount of ozone in the earth's atmosphere, and how far they correspond to changes in the intensity of emission from the sun. The amplitude of the solar diurnal magnetic variation changes, in parallel with the solar cycle, by amounts exceeding fifty per cent; it seems likely that these are due to changes in upper atmospheric ionization, themselves resulting from variations in the intensity of components of the ultraviolet solar radiation that are wholly absorbed in the upper atmosphere. These inferred changes in the intensity of solar radiation in the far ultraviolet are of greater magnitude than those found in the other parts of the solar spectrum, and suggest that the variability of the intensity increases with decreasing wave length. This is borne out to some extent by the measures of ultraviolet radiation made by Pettit, but there seems need for further investigation into the reality of the changes found by existing methods. Spectrophotometric measurements made by comparison with standard sources of radiation seem capable of giving increased precision**.

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* Proc. Roy. Soc. A.vol.123,p. 27, 1929, and vol. 130, p.668, 1931.

** See pp. 5, 6, 48, and 105.

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REPORT ON SOLAR AND TERRESTRIAL RELATIONSHIPS

By C. G. ABBOT.

The Smithsonian Institution is about to publish Volume V of the Annals of its Astrophysical Observatory. It will describe the establishment, instruments, methods, and operations of its three field stations - Montezuma, Chile; Table Mountain, California, and Mount Brukkaros, South West Africa. It will tabulate pyrheliometry and solar constant values, daily, ten-day, and monthly, from 1920 to 1930. Comparisons will show that the average deviation of solar constant values derived at two stations 5,000 miles apart in opposite hemispheres is 0.41 percent for individual daily results and 0.16 per cent for monthly mean results.

Since the probable error of the mean monthly values is so very small, only 0.06 percent, nearly every fluctuation of the curve of the observed march of solar variation is verified by cooperating stations. There can no longer be any question of the reality of solar variation.

The principal features and many details of the sun's variation since 1918 are found to be the sum of five regular periodicities. Their periods are 65, 45, 25, 11, and 8 months. Their amplitudes are 0.014, 0.013, 0.010, 0.009. and 0.005 calorie, respectively. Between times when they all reinforce each other to increase the solar radiation and to decrease it, there is a range of 0.102 calorie, or about 5 percent. This was not entirely reached at any time since 1918, the nearest approach of about 3 percent occurring in 1922.

Superposed on this background of fairly permanent long-period periodicities are many periodicities and also irregular solar fluctuations of shorter intervals. Among these are sequences of solar change running their course upward or downward in a week or less. We are able to discriminate these with fair certainty if they exceed 0.45 per cent by the daily observations of our best station. Montezuma. The other stations show sufficient evidence of correlation to establish a very strong probability of the veridity of these small changes, but have not sufficient accuracy or continuity to duplicate them all as we should like to see them do. However, the temperatures of Washington and other stations in the United States show so obvious a dependence upon these sequences of solar variation, discovered in the observations of Montezuma, Chile, as to be an independent verification of them.

A paper, summarizing some of the relations thus far found between solar changes and weather changes, entitled 'Weather Dominated by Solar Changes', Smithsonian Miscellaneous Collections, Vol. 85, No.1, 1931, has been published by C.G. Abbot. A friend of the Smithsonian Institution, Mr. J. A. Roebling, has been so much impressed by the promise of this line of research that he has financed an expedition under Mr. A. F. Moore, who will spend a year in Africa and nearby regions in search of a high desert mountain station as favorable for solar constant measurements as Montezuma, in Chile. Mr. Moore is now in South West Africa.

A slight correction to solar constant results, to eliminate the influence of variability of atmospheric ozone, proved necessary at the station, Table Mountain. A simple method for determining it by measurements of bolographs in the red-yellow-green region has been devised by C.G. Abbot. The method has lately been developed into an accurate independent method of measuring the quantity of atmospheric ozone by Dr.O.R. Wulf of the Department of Agriculture, who made bolometric and chemical researches at Table Mountain for that purpose, under a grant from Mr. J.A. Roebling. Dr. Wulf will shortly publish details and comparisons with simultaneous observations on Table Mountain by Dobson's method.

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ON ULTRA-VIOLET RADIATION

By Giorgio Abetti.

One of the outstanding problems of solar and terrestrial relationships is certainly that of the ultra-violet radiation. While several important investigations have been made and are being continued, we do not certainly know whether the observed changes in the ultra-violet sun-spectrum are of solar or atmospheric origin. The results obtained leave the following doubt: either the solar variations in the violet and ultra-violet are real and much larger than those in the other spectral regions, or the variations are small throughout the spectrum and are noticeable in the region of short waves only in consequence of the variations of transparency of our atmosphere, principally of the ozone bands.

Bernheimer[1] discussing the observations of ultra-violet radiation made at Mt. Wilson, Tucson and Arosa, concluded that they show an annual period with high values in winter and low values in summer, probably in consequence of the diminished transparency of the atmosphere in the latter season. So it seems necessary, before speaking of solar variations, to investigate the terrestrial conditions in the two hemispheres in order to eliminate the said annual period.

But the most important part of the problem to be solved is certainly to find the best method with which to observe this ultra-violet radiation. Those used with success by Fabry and Dobson are specially adapted to the investigations of the ozone, those of Abbot do not separate the ultra-violet from the general radiation, while the method of Pettit gives the ratio, ultra-violet to green, of a certain spectral region transmitted by his two filters.

If we consider the spectroscopic work which has been done with the stars, and in particular the microphotometer tracings for stars of different types or for Cepheid variables[2], we notice the considerable variations which take place in the ultra-violet region, not only in consequence of the variations of spectral lines, but also in the rate of increase of energy towards the greater wave lengths.

It seems therefore that if we could dispose of a special spectrograph for the ultra-violet, giving pure spectra and extended towards the ultra-violet, as much as possible, with a sufficient dispersion, it would be possible to make monochromatic comparisons in small spectral regions. For this it is of course necessary to dispose of a standard artificial source of radiation and then to study the spectra with the microphotometer. When such an instrument is available it will be necessary to choose proper stations for the observations. Two stations in the opposite hemispheres would permit the elimination of the annual terrestrial period. Also possibly a station in low latitude, with good climatic conditions and good atmospheric transparency, would also give valuable information.

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1. Handbuch der Astrophysik - Band IV - and Lund Obs.Circ. Nr.2.

2. See for example: Lick Observatory Bulletin - Nr. 422.

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ON THE MEANING OF THE CHARACTER FIGURES OF SOLAR ACTIVITY.

by Giorgio Abetti.

With the object of providing early information as to the varying conditions of solar activity, it was decided at the last meeting of the Astronomical Union to publish a quarterly bulletin of daily character figures of various solar phenomena. This publication, issued under the auspices of the Union, is entrusted to the Observatory at Zürich, where observations from stations scattered all over the world are collected. After three years' experience of the Bulletin and of the observations published therein it has been found possible to introduce several improvements. These are described by Professor Brunner, Director of the Zürich Observatory, in a memorandum included in this Third Report.

The object of this note is to elucidate some points relating especially to the calcium and hydrogen flocculi and their character figures. From the first it was noted that the figures representing the area and intensity of the flocculi, on a scale from 0 to 5, vary as between stations, and the variation is greater than the personal error admissible in forming the estimates. It is desirable to investigate the causes of these discrepancies with a view to eliminating them as far as possible.

The first cause is, undoubtedly, the degree of accuracy with which the second slit of the spectroheliograph is directed on to the H and K calcium lines or on the Hα hydrogen line. A slight shift of the slit to one side or the other of the centre of those lines leads to a change in the features of the flocculi both as regards their areas and their intensities. The second cause is due to atmospheric conditions, that is to the steadiness and transparency in the air. A third is that due to the different sizes of the solar image given by the various spectroheliographs employed; and the fourth is due to the diverse scales used at the different observatories for estimating the character figures, which results in a systematic difference between the various stations.

Generally speaking a mere examination of the spectroheliograms tells roughly whether the slit has been accurately centered on the spectral line or not. If we examine spectroheliograms obtained by directing the second slit to various parts of the line, gradually approaching its centre[1], the characteristic structure of the flocculi, with the slit at varying distances from the centre, will be readily recognized. The position of the second slit with respect to the spectral line can be checked by following the practice at Mount Wilson of photographing the position of the second slit and the line on the plate, both before and after taking the spectroheliogram. Another indirect method which shows up defective setting is that of comparing the characteristic numbers of the different stations. If at one station the slit has not been correctly centered on the line the differences noted at that station are in defect with respect to those noted between the other stations. This is as it should be, because the flocculi photographed outside the centre of the line are almost always smaller in area, less intense, and not so numerous as those photographed with the slit on the centre of the line. It is therefore easy to trace out and reject those observations which appear to be faulty.

The second cause can be avoided by rejecting all observations made under unfavourable atmospheric conditions. Regarding the third cause I have carried out some experiments at Arcetri

1. Handbuch der Astrophysik. vol.IV. Solar Physics, p. 112, Berlin, Spring, 1929.

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by mounting the Amici objective on the solar tower. The objective is of 28 cm. aperture and 529 cm. focal length, and produces an image of 49 mm. in diameter. A series of photographs taken on the same day, and almost at the same time, show that the bright and dark hydrogen flocculi which appear on the solar images of 49 mm. and on those of 170 mm., (the size of the image produced by the object glass of 18 m. focal length), do not affect the estimates of the character figures, provided the same standard scale is used. As to the fourth cause of the discrepancies, it is necessary to adopt one standard scale for all observatories which contribute estimates of the character figures of the calcium and hydrogen flocculi.

Out of a large number of spectroheliograms with a solar image of about 6 cm. taken at Mount Wilson, six of each kind of flocculi, calcium and hydrogen, have been selected as representing as closely as possible the intensity and area of the flocculi on a scale of 0 to 5. Naturally several years must elapse before a sufficient number of spectroheliograms can be obtained to allow of a thoroughly representative selection being made, in fact at Mount Wilson I found that two of the numbers of the scale did not correspond with sufficient approximation to those allotted to the spectroheliograms selected as standards. It is obvious that, given ever-increasing material to work upon, it will be possible, in time, to improve the standard scale; this matter is receiving attention at Mount Wilson. It would be a great help at present if copies of the selected spectroheliograms were distributed so that all stations might conform to that standard scale.

At the Arcetri tower, spectroheliograms of the hydrogen flocculi are taken regularly with a solar image of 5 cm., (the diameter of the image will shortly be increased to 6 cm. by using a new objective) and for the central zone the image of 17 cm. is used.

Attention to the above considerations will probably result in greater uniformity among the different stations, and will also facilitate and simplify the determination of systematic errors and the reduction of the observations to a given standard by means of correction factors, as has been done by Howell Brown[2], and as will be done in the International Bulletin beginning with 1931[3].

In the Bulletin, the character figures are given, not only for the whole of the solar disc, but also for a central zone whose diameter is equal to the semidiameter of the sun's disc. This is done in order to facilitate the study of the relation between solar and terrestrial phenomena, on the hypothesis that terrestrial disturbances occur only when solar eruptions and other outbursts take place in regions not far from the central meridian. But the fact remains that if the estimates for the central zone and for the whole disc, given in the Bulletin, are compared, it is found that the former are always systematically less than the latter. The difference may be partly explained by a foreshortening effect, but it must also be due, in part, to the fact that the two estimates are not, as they should be, independent of each other. However this should not prejudice the study of the fluctuations in solar activity, either in the central zone or over the whole disc, so long as the same method of estimating is adopted.

Notwithstanding what has been said above it can be shown that the character figures, even those of the past three years, do provide the information required, at least so well as the sunspot relative numbers, by comparing the frequency curve of the relative numbers with those of the character figures for the calcium

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2. Howell C. Brown. Correction Factors and Corrected Daily Means of the Solar Indices as given in the International Astronomical Bulletins. Terrestrial Magnetism and Atmospheric Electricity, December 1930.

3. W. Brunner. (This Report).

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flocculi and the bright and dark hydrogen flocculi. Only the character figures for the central zone for 1928 having been published, these have been compared with the relative numbers of sunspots in the central zone; the relative numbers of the sunspots in 1929 and 1930 have been instead compared with the character figures for the whole disc (Fig. 1). It will be seen that the fluctuations of the various phenomena are actually the same in the case of the spots, the calcium flocculi and the bright hydrogen flocculi, hence their activity indices are correlated. Although the hydrogen flocculi behave much in the same way, yet there are divergences, partly due to the phenomenon itself, and partly, probably, to the circumstances mentioned above. When those sources of error have been eliminated we shall be in a better position to investigate the causes of the divergences. It is still premature to draw definite conclusions from this triennial period,

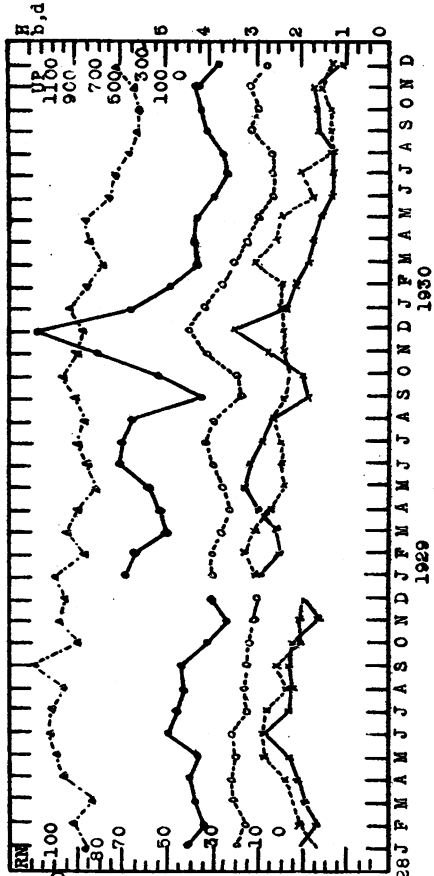
H,d
UP
RN
C
F
1928 J F M A M J J A S O N D J F M A M J J A S O N D
1929
1930
UP. Units of prominence (Arcetri-Catania-Zurigo)
RN. Relative numbers of spots.
CF. Calcium flocculi (K)
Hb. Hydrogen Bright flocculi (H)
Hd. Hydrogen dark flocculi (H).

Fig. 1. Units of prominence, relative numbers and character figures from 1928 to 1930.

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yet the diagrams seem to show that though the curves for the spots and for the bright calcium and hydrogen flocculi show that these phenomena occur almost contemporaneously (the flocculi appear just a little earlier than the spots), the dark hydrogen flocculi on the other hand seem to delay somewhat with respect to the spots. This fact, if confirmed, is in agreement with the generally accepted hypothesis of the level and formation of the bright and dark flocculi. It is also interesting to compare these results with those obtained by the visual observations of the prominences at the limb of the sun. If we compute the monthly means of the units of prominence (I^0 of the limb X I'' in height) observed at Arcetri, Catania and Zurich in the period 1928-1930 we have:-

Monthly Means of the Units of Prominence
(Arcetri-Catania-Zurich)

	1928	1929	1930
January	821	1124	957
February	944	843	802
March	764	1015	656
April	1037	892	806
May	1102	722	829
June	1162	806	601
July	1143	911	550
August	1000	844	418
September	1313	907	334
October	889	1036	332
November	1081	891	376
December	999	850	551

With these figures the curve in the upper part of Fig. 1 has been drawn. In it we notice a general decrease of the solar activity from 1928 to 1930, but the variations of short period, which are prominent in the curves of the relative numbers of the spots and of the character figures of the bright calcium and hydrogen flocculi, are not well defined in the curve of the prominences. This is easy to understand when we consider that these visual observations are limited to the limb of the sun. Perhaps the prominences at the limb, like the dark hydrogen flocculi, have a slight retardation with respect to the spots and bright flocculi.

To complete the data relating to solar activity we shall shortly be furnished, thanks to international cooperation, with the results of observations made with the Hale spectroheliograph, which will supply information as to the radial velocities of the flocculi, and hence with data regarding the activity and rapidity of solar disturbances affecting terrestrial magnetism.[4]

4. cf. H. W. Newton's observations at the Greenwich Observatory. Monthly Notices, March 1931, p. 593.

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The measures of the intensity of the sun's ultra-violet radiations are also of great importance; they are given in the last triennial Bulletin based upon Pettit's observations at Mount Wilson, in the form of a ratio of ultra-violet radiations (for $\lambda = 0.32\mu$) to green ($\lambda = 0.50\mu$).

The experience of the last three years tends to show with practical certainty that the annual variation of the ultra-violet radiations is not, as was first supposed[5], due to solar activity, but that it is more probably due to variations in our own atmosphere[6]. This appears to be confirmed by the observations on atmospheric ozone, which point to its close connection with the atmospheric conditions in the upper atmosphere[7]. The interesting point which obviously emerges from these researches is the question of the systematic study, with suitable methods and under the most favourable atmospheric conditions, of the ultra-violet solar spectrum in various latitudes, in order to sort out the observed variations into those due to the sun's activity and those which are caused by the terrestrial atmosphere.

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5. Pettit. Ultraviolet Solar Radiation. Proceed. Nat. Acad. of Sciences. June 1927. vol. 13, p. 231, Washington.

6. Bernheimer. Remarks regarding Ultraviolet Solar Radiation. Lund Observatory Circular. No.2. March 31st, 1931; also this Report.

7. cf. e.g. Dobson. Ozone in the Upper Atmosphere and its Relation to Meteorology. Nature, No.3209, May 2nd, 1931, p.668.

SOLAR ACTIVITY AND RADIOTELEGRAPHY

by L. W. Austin.

Since the last report of the Committee on Solar and Terrestrial Relationships of the International Research Council, the evidence for the reality of a connection between solar and terrestrial magnetic activity on the one hand, and radio wave propagation and atmospheric disturbance on the other, has been considerably strengthened.

Some uncertainty has been caused by the difference in the behaviour of radio waves of different wave lengths under the influence of magnetic storms, but the main facts thus far ascertained are as follows:

The sensitiveness of radio transmission to magnetic storms decreases with the wave length[2.9.12.13]. Below sixty meters, even slight storms are generally accompanied by radio disturbances. In this range of wave lengths the effect appears always to be a depression of signal strength both by day and night. The signal depression usually reaches its lowest point on the day of the greatest magnetic disturbance, with a gradual rise to normal values continuing for several days[12]. According to Maris and Hulburt[10], when a magnetic storm starts, only those short wave radio paths are affected which lie on the daylight side of the earth; those on the dark side remaining quiescent until dawn. This is in agreement with their theory which ascribes magnetic storms to a flash of ultra violet light from the sun. The influence of magnetic storms on short wave radio transmission is generally (but not always) more marked in the case of signal paths at right angles to the magnetic meridians than on those parallel to them; the effects being greater, the nearer the paths lie to the magnetic poles. According to T. L. Eckersley[15], the number of periods in the year from October, 1927 to October, 1928, in which magnetic storms rendered short wave communication impossible between England and Montreal, were 49; between England and New York 32; while between England and points to the southward, in Australia, South Africa,

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India, and South America, these periods varied from four to seven.

In the range of wave lengths from 200 to 500 meters, the most noticeable effect of magnetic storms is a depression of night signals[3.4.5]. There seems to be no certain information concerning daylight effects.

At a wave length of 5,000 meters, the magnetic disturbances sometimes are accompanied, but more often are followed after a delay of one to three days, by a daylight strengthening of signals amounting to from 30 to 75 per cent, and a marked night depression with a gradual return to normal conditions[2.9.12]. At very great wave lengths, above 10,000 m., the effects of magnetic storms on transmission become much less marked. Too few observations on European stations have been made at the Bureau of Standards during the hours of all-darkness signal path to give any information regarding such relationships. The partial-darkness path signals received about 3 p.m. appear to vary in general with the all-daylight signals of the morning reception. Some observations of the Bell Telephone Company[2.9], however, have indicated that the night depression effect exists at 17,000 m. At these wave lengths the connection between the storms and the daylight signals is so slight that, with the exception of occasional instances[11, 17], it is only made evident by averaging the effects of a large number of storms. Miss Wymore[11] has shown by statistical methods that the maximum rise in Washington of very long wave European daylight signals comes as a rule from one to three days after the height of the magnetic storm.

According to Appleton[14], the increase in signal strength of long wave stations at the time of a magnetic storm is due to the increase of ionization of the Kennelly-Heaviside layer at that time, the long waves being turned back to earth at its lower surface by a form of reflection which is increased as the ionization becomes greater. The short waves, on the contrary, are weakened by the increased ionization since they penetrate the layer more deeply and are subject to increased absorption.

Figure 1 shows the monthly averages of the daylight signals from several 10,000 to 20,000 m. European stations as measured at the Bureau of Standards[18] from 1924 to 1930. The figure also shows the monthly averages of sun spots and of the horizontal magnetic range* as measured at Cheltenham, Maryland, for the same period. It is seen that the sun spot curve does not show much resemblance to the curve of signals nor of horizontal magnetic range, but that the resemblance between the two latter curves is very striking.

Figure 2. shows the yearly daylight signal, sun spot and horizontal range averages from 1915 to 1930ø, inclusive. The signal measurements were taken at the Bureau of Standards[6.18] from 1915 to 1923 on the 13,000 m. station at Nauen (Berlin). During this time the shunted telephone method was used in the measurements, and the accuracy is much less than in the later years. From 1924 the curve is made up from observations on a number of European Stations having wave lengths between 10,000 m. and 20,000 m. The great increase in strength of signal in 1930 and the increase in magnetic activity in spite of the fall in the number of sunspots is noteworthy. The long-wave daylight signal intensities began to rise sharply in March, 1930, reached a maximum in August and even at the present writing (February 1931) continue to be above normal. During the summer of 1930 the short wave communication was reported to be the weakest thus far experienced, illustrating apparently the opposite effect of magnetic activity on long daylight waves and on short waves.

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* The horizontal ranges at Cheltenham have not been calculated since August. 1930.

ø The horizontal range average for 1930 is for the first half of the year.

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Figure 3 represents the annual averages of the 3 p.m. atmospheric disturbances measured in Washington at a wave length of 12,500 m., as compared with the sun spot numbers from 1918 to 1930*. The dotted part of the disturbance curve is less accurate than the part represented by the solid line. It appears from this that there is very probably an inverse relationship between the annual averages of long wave daylight atmospheric disturbances and sun spot numbers when averaged in periods of a year or more. Very little success has attended the effort to show a connection between the disturbances and solar and magnetic activities when averaged in periods of less than a year, probably on account of the disturbing influences of weather variations.

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* In the last report of this Committee, page 18, similar curves were shown up to 1926.

1. Fessenden, R.A., Wireless Telephony, Proc. A.I.E.E., 27, p. 1339: 1908.
2. Espenschied, L., Anderson, C.N. and Bailey A. Transatlantic Radio Telephone Transmission. Proc. I.R.E., 14, p.7: 1926.
3. Pickard, G.W. Correlation of Radio Reception with Solar Activity and Terrestrial Magnetism I. Proc. I.R.E., 15, p. 83: 1927.
4. Pickard, G.W. Correlation of Radio Reception with Solar Activity and Terrestrial Magnetism II. Proc.I.R.E., 15, p. 749, 1927.
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6. Austin, L.W. Long Wave Radio Measurements at the Bureau of Standards in 1926 with some Comparisons of Solar Activity and Radio Phenomena, Proc.I.R.E., 15, p. 825, 1927.
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9. Anderson, C.N. Correlation of Long Wave Transatlantic Radio Transmission with other Factors Affected by Solar Activity. Proc.I.R.E., 16, p. 297, 1928.
10. Maris, H.B. and Hulburt, E.O. Wireless Telegraphy and Magnetic Storms. Proc. I.R.E., 17, p. 494: 1929.
11. Wymore, I.J. The Relation of Radio Propagation to Disturbances in Terrestrial Magnetism. Proc. I.R.E., 17, p. 1206: 1929.
12. Anderson, C.N. Transatlantic Radio Transmission. Proc. I.R.E. 17, p. 1528: 1929.
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14. Appleton, E.V. Solar Activity and Wireless Transmission. Second Report of this Committee , p. 16: 1929.
15. Eckersley, T.L. An Investigation of Short Waves. Journal I.E.E. (London), 67, p. 992: 1929.
16. Austin, L.W. Solar Activity and Radio Transmission. Second Report of this Committee, p. 18, 1929.
17. de Mars, P.A., Kenrick, G.W. and Pickard, G.W. Low Frequency Radio Transmission. Proc. I.R.E., 18, p. 1488: 1930.
18. Austin, L.W., Judson, E.B. and Shiel, I.J. Wymore. Solar and Magnetic Activity and Radio Transmission. Proc.I.R.E., 18, p. 1997: 1930.

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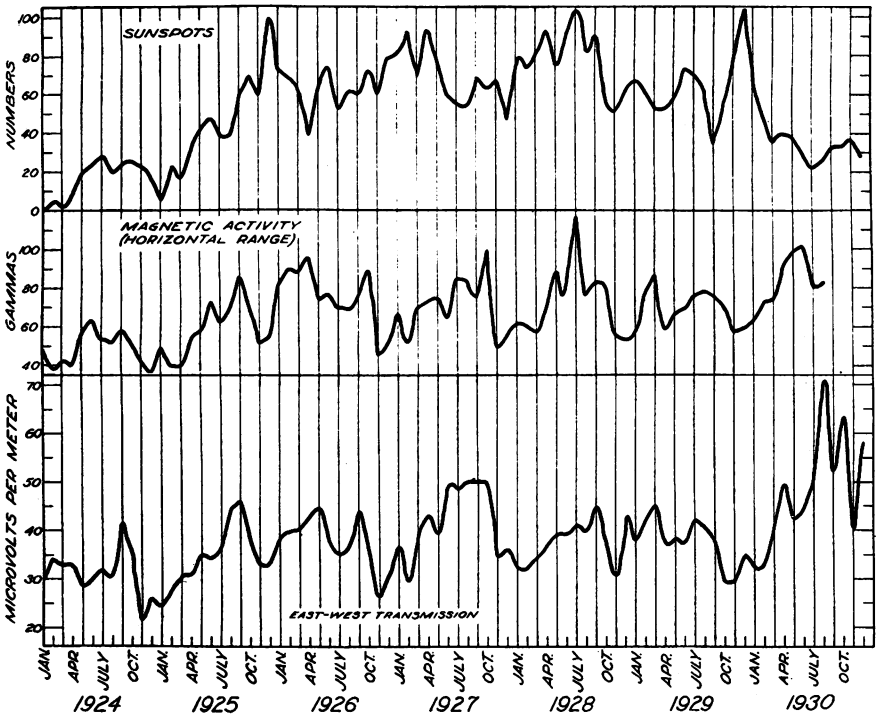

Fig. 1. Monthly averages of daylight signals from several European stations, 10,000 to 20,000 meters wave length, measured at the Bureau of Standards from 1924 to 1930, with the monthly averages of sunspot numbers and the horizontal magnetic range.

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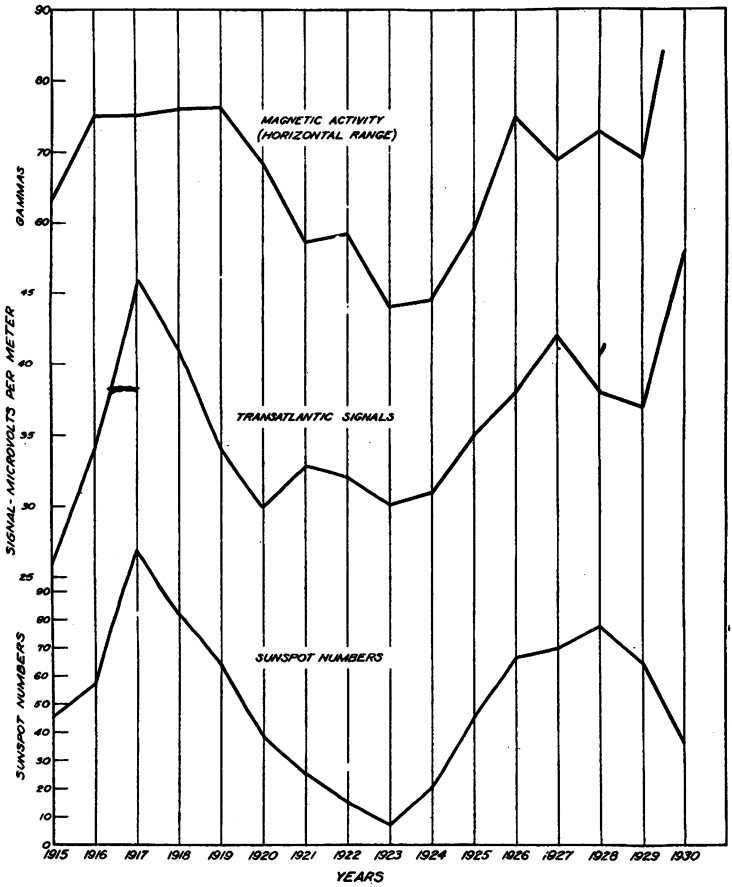

Fig. 2. Annual daylight signal averages from several European stations, 10,000 to 20,000 meters wave length, measured at the Bureau of Standards from 1915 to 1930, with the annual averages of sunspot numbers and the horizontal magnetic range.

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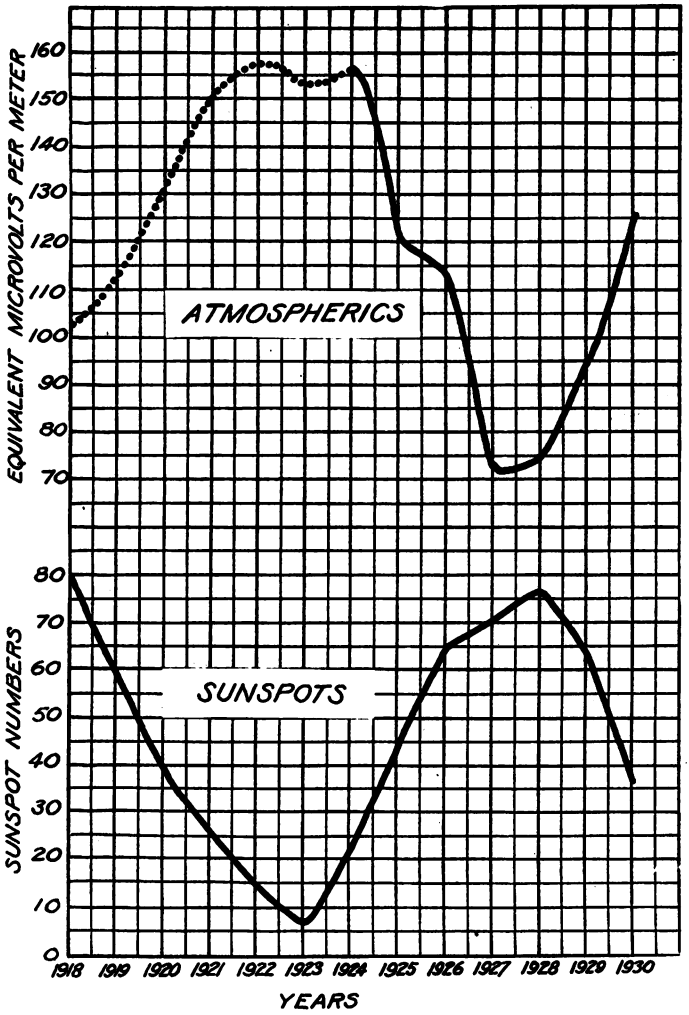

Fig. 3. Annual averages of atmospheric disturbances, 12,500 meters wave length, at Washington, 3 p.m., E.S.T., and sunspot numbers, from 1918 to 1930.

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ULTRAVIOLET SOLAR RADIATION AND ITS RELATION TO THE SOLAR CONSTANT, SOLAR ACTIVITY, THE OZONE CONTENT AND THE TURBIDITY OF THE EARTH'S ATMOSPHERE.

By Walter E. Bernheimer.

The valuable series of measurements of ultra-violet solar radiation, continuously made since April 1925 by E. Pettit[1] are of great interest in regard to the variations of solar radiation and associated processes in the earth's atmosphere. Pettit ststes that the march of observed oscillations in the ultra-violet solar radiation remains essentially unchanged regardless of whether the values are determined for air mass one or zero. He interprets this as showing that the atmosphere plays no important part and is effectively eliminated. On this view the observed variations should be regarded as really a solar phenomenon. The present writer, in a paper published recently in Lund Observatory Circular No. 2 (1931) has developed another view, which seems to indicate that the measurements are influenced by disturbances of the earth's atmosphere, and that for this reason the variations cannot in the main be ascribed to variations in the sun itself. A final decision between these two views would be of great interest, perhaps not so much in regard to solar and terrestrial relationships as to the problems of solar and stellar variability in general. It is quite clear that with relatively poor material, covering not yet a full solar cycle, it would be premature to seek to make such a decision at once. On the other hand the present material indicates a tendency which may be of some value in the next steps of the future work on this problem.

Pettit's method gives the ratio ultra-violet (λ3200) to green (λ5000). Then assuming that radiation at λ5000 is constant through the period considered, one must ascribe variations of the ratio to fluctuations of the ultra-violet solar radiation. The variations observed were at first very large, but became smaller in later years, on account, I believe, of higher accuracy in measurement. It was found in 1927[2] that measurements of ultra-violet solar radiation between April 1925 and March 1927 show an annual period, indicating a certain influence of the earth's atmosphere on the measured quantities. It is significant that this annual period also appeared in the later material[3]. To-day it is possible to study a material of 69 months from April 1925 to December 1930, including observations on 1312 days. It will be seen from Figure 1 E that the annual period is well marked. The maximum occurs between January and February, the minimum between July and August, exactly six months later. This result is difficult to reconcile with the view[1] that the variation originates in the sun itself. It is interesting that variations also of the solar constant, measured between July 1919 and July 1924, including observations on 1080 days, show a similar annual period.[4] But it may be mentioned that the recently published[5] measurements of solar constant between 1927 and 1931 no longer show such a tendency.

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1. cp. E. Pettit, 1. Report p. 54 (1926)
   2. Report p. 91 (1929) Here is also given a short résumé on the method employed.
2. W.E. Bernheimer, Die Naturwissenschaften 16, p.26.
3. " " Handbuch d. Astrophys. IV (1929) Monthly Weather Rev. 57, p.412 (1929-30) and Lund Obs. Circ.No. 2 (1931)
4. Lund Observatory Circ. No.2 (1931)
5. Smiths. Misc. Coll. (1931).

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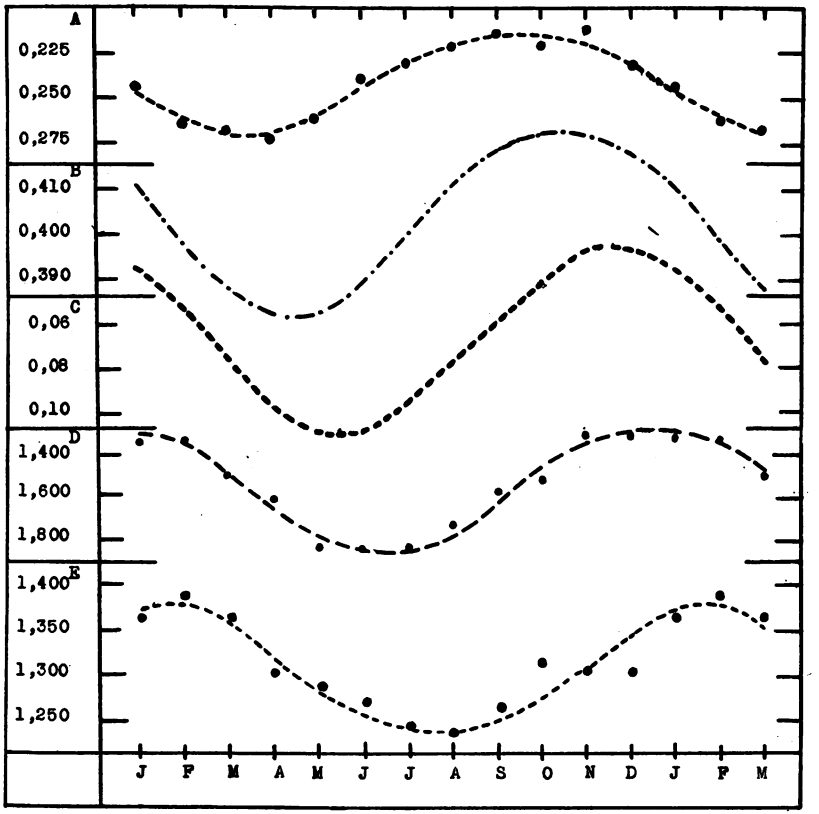

Figure 1.

A. Annual period of Ozone amount in the Earth's atmosphere, observed in California.
B. Annual period of the transmission-coefficient at λ3200, observed in Arosa.
C. Annual period of Ångström's coefficient of turbidity β, observed in Stockholm.
D. Annual period of Linke's factor of turbidity p, observed in Arosa.
E. Annual period of extra-terrestrial ultra-violet solar radiation, observed at Mount Wilson, California and Tucson, Arizona.

On the other hand an 11-month period, recently found by Abbot in the solar constant measurements, does not occur in the measurements of ultra-violet solar variation.

Formerly it was supposed[6] that ultra-violet solar radiation was the chief cause of the ozone present in the earth's atmosphere, and that high values of ultra-violet solar radiation were associated with low values of ozone amount. This cannot, I

6. E.Pettit, Wash.Nat.Proc, 13, p.380 (1927), Ch.Fabry, First Report (1926) on Solar and Terrestrial Relationships.

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believe, be the case. In Figure 1 A is reproduced the annual period of ozone content, observed in California, i.e. in practically the same latitude as Tucson, where the measurements of ultra-violet radiation are made. Comparing Figure 1 A with 1 E it will be seen that there is a phase-difference of four months between the two annual periods. This result seems to be in fair agreement with the recent statement of G. M. B. Dobson[7] that ozone cannot be directly caused by ultra-violet solar radiation.

In Figure 1 B is shown the annual period of the transmission-coefficient for wave-length λ3200, observed in Arosa. Here is a phase-shift of three months. The two next curves below show the annual period of atmospheric turbidity measured for total radiation. Figure 1 C gives for Stockholm the march of the very significant coefficient of turbidity β, recently developed by A. Ångström.[8] The phase-shift amounts only to two months, and in Figure 1 D to no more than one month. The latter curve shows for Arosa the march of the factor of turbidity p (Trübungsfaktor) developed by F. Linke. The agreement between the curves of turbidity (especially 1 D) with the observed annual period of ultra-violet solar radiation is very striking. It seems thus that the seasonal conditions in the earth's atmosphere are reflected in the variations of the ultra-violet solar radiation, and consequently the variations of the latter for the main part are independent of solar phenomena. One must conclude that as yet the influence of the earth's atmosphere cannot be fully eliminated in the measurements of ultra-violet radiation. It is very desirable to obtain a greater elimination in the future. The present writer suggested in 1929[9] and 1931[10] the advantage of making simultaneous observations at a second station situated in the southern hemisphere. In this way the annual variation found could easily be tested, and should give at the southern station evidence of an annual period with a phase shift of six months. Simultaneous observations in the equatorial regions also would be of interest concerning the ozone problem. As Dobson has shown,[12] in Chile ($\varphi = -22°$) there is practically no annual variation in the amount of ozone.

If the annual variation of ultra-violet solar radiation exists, then it would be quite possible to predict the order of magnitude of the monthly means. It is easy to understand that a real connection between ultra-violet solar radiation and sun-spot relative numbers based on physical causes cannot be present. This seems in fact the case inasmuch as the factor of correlation between ultra-violet solar radiations and solar activity for 66 monthly means April 1925 - September 1930 is not more than -

$$r = + 0.209 \pm 0.118,$$

and for three month averages:

$$r = + 0.289 \pm 0.195.$$

Their comparatively parallel march before July 1927[13] seems to be only accidental, which is seen if we calculate smoothed monthly means of ultra-violet radiation in like manner and according to the same formula as in the Zurich 'ausgeglichene Relativzahlen' for

7. G.M.B. Dobson, Nature, May 2, 1931.
8. A. Angstrom, Geogr. Annal. XII. p. 130 (1930)
9. Handb. d. Astroph. IV (1929) and Monthly Weather Rev. 5,7. p.412.
10. Lund Obs. Circ. No.2. 1931.
11. Nature, May 2, 1931.
12. Second Report on Solar and Terrestrial Relationships. Figure. p.92.

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sunspots. In this way in both curves secondary fluctuations will be eliminated: a comparison between the two phenomena is shown in Figure 2. (1) The measurements of ultra-violet solar radiation obviously show besides the annual period a remarkable march, which is much more steady than that of sunspot activity. (2) The rapid change of ultra-violet radiation between December 1926 and May 1928 is not shown at all in the march of the sunspot numbers. It will be very difficult to find the physical cause of this phenomenon. (3) Contrary to earlier views the values of the ultra-violet solar radiation reach a minimum just when the sunspot numbers reach their maximum in the 11-year solar cycle. (4) After sun-spot maximum (1928,4) to the end of 1930 the smoothed sun-spot numbers fall off from 78 to 2.9, while in this period the ultra-violet solar radiation has scarcely changed.

Just as the correlation between ultra-violet solar radiation and solar activity is negligible, so also is that between the solar constant and the solar activity, contrary to earlier views. F. Baur[13] found for 129 monthly means between July 1918 and March 1929:

$$r = + 0.19 \pm 0.08.$$

The recently published values of the solar constant[14] make it possible to treat the material to April 1931. The general march without secondary fluctuations, calculated in like manner as for the ultra-violet solar radiation, is shown in the upper part of Figure 2. It will be seen that the solar constant reaches a maximum about half a year before sunspot maximum. The minimum of the smoothed solar constant occurs in April 1929: after this time the values become successively higher, and reach nearly a maximum in the spring of 1931, whilst sunspot relative numbers in general are falling off from maximum to the approaching minimum in the solar cycle.

It seems therefore as though solar radiation were quite independent of solar activity. A direct comparison between the march of ultra-violet solar radiation and the solar constant (• and × in the upper part of Figure 2) reveals a tendency somewhat fatal to the theory that both quantities are correlated and have a common physical source. If the reality of a fluctuation in the total and the ultra-violet radiation should be proved, much further work will be needed to find the cause for the strange fact that solar radiation measured in the main spectrum, and solar radiation measured in the short wave-lengths, manifest a quite different behaviour, and that the march of both quantities is obviously not related to the general variations of solar activity. We may also state that aurorae and terrestrial magnetism are the only phenomena which obviously vary in accordance with the solar activity.

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13. Meteor. Zeitschr. 46, p. 47 (1930)

14. C.G. Abbot. Smiths. Coll. No.90 (1931).

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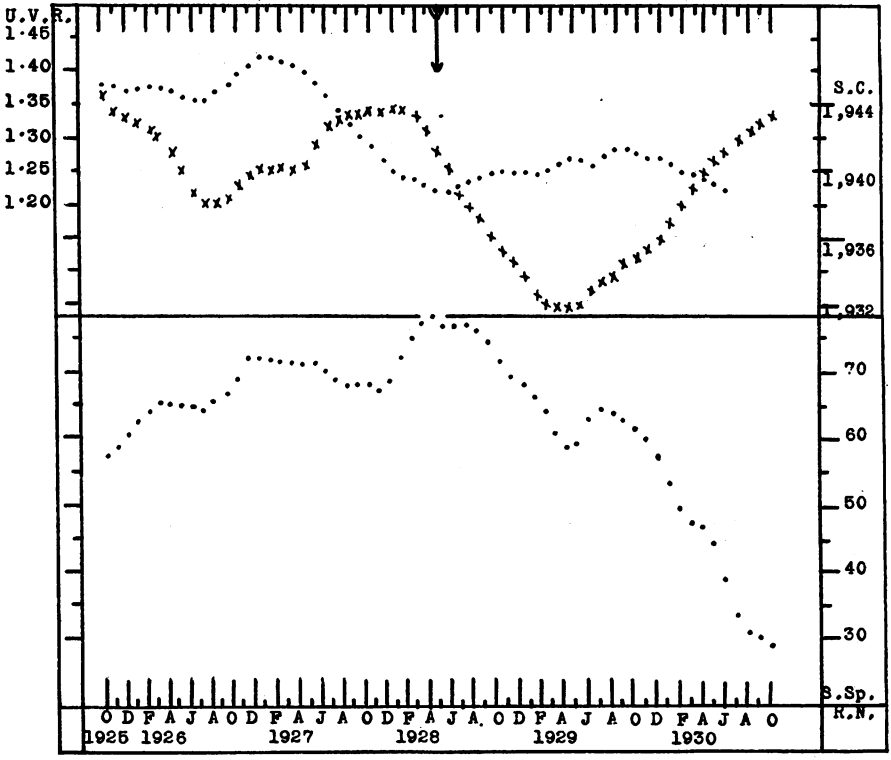

Figure 2.

Above: • The general march of ultra-violet solar radiation.
x The general march of solar constant.

Below: The general march of sun-spot relative numbers.

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NIGHT RADIO RECEPTIVITY MEASUREMENTS PARALLEL TO THE MAGNETIC MERIDIAN.

By Howell C. Brown.

Beginning July 1927 nightly field strength measurements of one hour's duration have been made by me, at Pasadena, California, of a broad-casting station in San Francisco 559 kilometers distant. In September 1929 a new station was added, KSL in Salt Lake City, Utah, with a frequency of 1130 kc/sec, distant 994 kilometers. The San Francisco series was begun with station KFWI on a frequency of 1120 kc/sec. but in June 1928 it was found necessary to shift to KPO, on a frequency of 710 kc/sec. and 1.0 kw power, as local interference prevented worth-while recording of the first station. The shift was made after a series of ten nights' overlapping observations to obtain a correction factor and thus prevent a break in the curves. April 1929 KPO shifted to a frequency of 680 kc/sec and a power of 5.0 kw. As the original station had a power of 0.5 kw all observations since the shift have been reduced to that level. The two stations being measured are approximately about the same angular distance East and West of the magnetic meridian. It would have been better to select stations directly North or South of the observing point, but no such stations were available. Despite the forced changes of power and frequency it is believed that the data furnish a reasonably homogeneous series for correlation work with solar and terrestrial elements.

All previous observers have measured stations whose transmission path was across the magnetic meridian while my measurements, although not parallel with the meridian, have a large component that is so, and thus furnish a basis for a comparison with other work done in the East-West line. It will be necessary, in all probability, to continue the measurements through a complete solar cycle before drawing definite conclusions, but a few general comparisons may be attempted at the present time.

PERIOD.

Pickard [1.] shows that the E-W transmission has a fairly regular period of fifteen months while the N-S path has one of thirteen months. The two curves march fairly well together but are dephased.

SUN SPOTS.

Pickard [1.] has shown that with the E-W path there is an inverse relation with sun spots but, so far, my series gives a weak, direct relation.

MAGNETIC FIELD.

Pickard [1.] and other observers with measurements on the E-W path find an inverse relation, but the N-S path seems to show little, if any, correlation with the earth's field. An examination of 33 magnetic storms, in which the range was 100 gammas or greater, does not reveal any measurable effect.

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1. Correlation of Radio Receptivity with Solar Activity and Terrestrial Magnetism. Greenleaf W. Pickard, Proc. I.R.E. Vol. 15, page 83 ..... Feb. 1927 Vol. 15, page 749 .... Sept. 1927.

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TEMPERATURE.

Pickard [2.] shows a direct relation with temperature on the E-W path and also with my series. However his conclusions in regard to my measurements were based on a rather short series, and he later called my attention to the fact that, as more observations were available, the N-S path seems to show that both rises and falls of temperature depress reception.

KPO and KSL in general rise and fall together but, at times, they depart from this relation. It may be that, after the KSL series becomes long enough to furnish sufficient data, a comparison of such 'off' nights will reveal facts of value.

Reception measurements are so masked by many factors that a long series is necessary before effects begin to show. For that reason any conclusions I have drawn may be greatly modified after more time has passed, and should be looked upon more as preliminary reports of progress than as definite conclusions. Observations will be continued through a complete sun spot cycle, and longer if necessary.

Those interested in the subject will find a fairly complete bibliography in the article - Summary of Progress in the Study of Radio Wave Propagation Phenomena - G. W. Kenrick and G. W. Pickard, Proc. I. R. E. Vol. 18. page 649 .... April 1930.

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2. Some Correlations of Radio Receptivity with Atmospheric Temperature and Pressure. Proc. I.R.E. Vol. 16, pages 765 ..... June 1928. Greenleaf W. Pickard.

ON THE CHARACTER FIGURES FOR SOLAR PHENOMENA.

by W. Brunner.

For the investigation of the relationship between solar phenomena and certain terrestrial phenomena it is important to have simple character figures which denote the daily intensity of the various phenomena of the photosphere and the chromosphere of the sun. On the initiative of the Committee of Solar and Terrestrial Relationships and on the proposal of the Committee of Solar Physics it was resolved at the last meeting of the International Astronomical Union at Leiden to publish a quarterly bulletin for such index numbers. The Swiss Federal Observatory (Eidgenössische Sternwarte in Zürich) has been charged with the collection of the material and the publication of the bulletin. Cooperating observatories are: Arcetri-Firenze, Cambridge (England), Catania, Coimbra, del Ebro, Ewhurst (Mr. Evershed), Greenwich, Kodaikanal, Lyons, Kiew, Meudon-Paris, Mount Wilson, Roma/ Campidoglio, Stonyhurst, Tokyo, Zurich.

The bulletin contains daily character figures for spot activity, for calcium-flocculi, bright and dark hydrogen-flocculi and for the intensity of ultraviolet rediation. The spot and flocculi numbers are given for the whole disc and for a smaller

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central part of the sun's surface which is turned more directly towards the earth. The central area is a concentric circle of diameter equal to the semidiameter of the sun's disc.

The character figures for flocculi are assigned on a scale of numbers 0 - 5. The numbers refer to the area and intensity of the flocculi, 0 representing absence or extreme rarity of flocculi and 5 extreme abundance and intensity. Special disturbances, unusual brilliancy, great changes of activity are mentioned in foot-notes. The flocculi are stated separately for the different observatories and the daily mean is taken.

The intensity of spot activity for the whole disc as well as for the central zone is expressed for each day by the Wolf relative spot number r = k (10g + f), where g indicates the number of the observed groups (Centers of activity) and f the total number of single spots or nuclei.

The factor k is the reduction factor on Wolf's unit. It varies with the instrument, the observer and the mode of observation. I have determined my own reduction factor on Wolf's unit by comparison of my observations with those of Professor Wolfer for the period 1926-1929. The factor is exactly the same as Professor Wolfer's, i.e. 0,60. It is smaller than Wolf's unit because we count more smaller nuclei than Wolf did and we pay more attention to the fact that large umbra-spots are mostly themselves broken up into various nuclei.

Passages of large or average sized groups through the central meridian, new formations of spot groups and entrance of a large or average sized centre of activity on the east limb are pointed out by special remarks in the bulletin.

The figures for the intensity of the ultraviolet radiation give the ratio ultraviolet (= 0,32) to green (= 0,50), ratio for June 1924 = 1.

The 'Bulletin for character figures for Solar phenomena' is now in hand for the last three years. The experience thus gained suggests the following remarks.

On going through the figures for the calcium-flocculi and the bright and dark hydrogen-flocculi it is evident that the figures for the same day from different observatories deviate from each other. It is necessary to seek the causes of these deviations and to make an attempt to correct the numbers in some manner to get better average values for each day.

The numbers are not determined by measurements but by estimation only and attention is paid simultaneously to the area and the intensity of the flocculi. A certain dispersion in the values of the different observatories for the same day is therefore to be expected. Deviations of one unit in the scale 0 - 5 have to be taken into account particularly at times of greater flocculæ activity. An examination of the present index numbers of the Ca-flocculi, whole disc, for 1929 shows out of 364 days of observation 50 days with differences up to 1,5 units, whereas for 1930, out of 365 days of observation such high deviations only occur on 9 days. In this statement are not included the figures of one station which started cooperating only last July, and the estimates of which are considerably below the other 5 observatories. The above striking decrease of greater differences is probably due to the decreasing solar-activity for spots and flocculi, but also to the greater experience and practice in estimating the character numbers.

In the central zone great differences of the figures for Ca-flocculi are more frequent, and they are still more frequent for the bright and dark hydrogen-flocculi in the central zone as well

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as in the whole disc. Going closer into these figures we find that the deviations of the different observatories for the same day are partly due to the uncertainty of estimating the plates, but partly they are also of a systematic character.

The following figures taken from the Mt. Wilson and Meudon series will show what could be obtained.

For the Ca-flocculi, whole disc, Mt. Wilson and Meudon have 221 corresponding observations for 1929; for 113 days they denote the same index number, and for 107 days the difference is one unit. In one case only the difference is 2 units. For the year 1930 with a smaller activity for spot and flocculi 109 numbers fully agree out of 175 corresponding observations; 30 numbers show a deviation of 0,5 units, 35 differ one unit, and again only on one day we have a difference of 2 units. For the central zone the agreement is somewhat weaker, probably on account of the difference of time at which the spectroheliograms have been taken at Mt. Wilson and at Meudon. The difference in time corresponds on the average to a difference of 5° in the heliographic longitude of the central meridian. For 1929 from 221 corresponding estimations at Mt. Wilson and Meudon 108 fully agree, 99 differ one unit and 14 differ by 2 units. For 1930, out of 175 corresponding figures 105 fully agree, 12 show a difference of 0,5 unit and 58 figures differ by one unit. There were no greater differences than one unit during 1930.

For the bright and dark hydrogen-flocculi the daily reports vary more, and show on the average a systematic character. Undoubtedly this is partly due to the different spectroheliographs used at the various stations. Probably the fact that the quality of H_α-images is usually more unequal than those of the K line in Calcium is responsible for the more frequent and greater divergences in the index numbers of bright and dark hydrogen-flocculi against those of Ca-flocculi. In fact the reversals of line H_α which create the bright flocculi are materially closer in Angstrom units than the bright reversals of the line K for Calcium. Hence it follows that with equal dispersion a given error in the position of the second slit of the spectroheliograph affects the aspect of the H_α-images more than those of Ca.

A further source for greater deviations in the index-numbers may also be in the smaller number of observations obtained. In order to determine the index-number for a fixed day it is necessary to examine, whenever possible, the plates of the days before and after the day in question. By this method too high or too low estimates can be avoided. The constancy and reliability of estimating the index-numbers will be greatly improved when the observers pick out plates from their material which are considered typical for the character numbers and use them as standards of comparison.

So far we have given in the Bulletins the indices for every single cooperating observatory. These figures have then been averaged to obtain the daily mean. We shall continue to publish the reports of each individual station as has been done hitherto. But as the daily reports from the cooperating observatories vary so greatly it will be better to make a corrected average for each day as is done for the Zürich relative sunspot numbers, taking one station with many observations as standard series. By comparing the corresponding observations of the other stations with the number of the standard series, we determine the reduction factor on the standard series for a three month-period, and then fill up any gaps in the standard series by the average of the reduced numbers of the other observers. One might object to this method that it gives too great a weight to the chosen standard series. Therefore, in order to obtain a series of better averaged daily means it may be preferable to adopt the method suggested by Howell C. Brown in his paper 'Correction-factors and Corrected Daily Means of the Solar Indices' as given in the International

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Astronomical Union Bulletins (Terrestrial Magnetism, December, 1930). One uses the reports of all observatories having a sufficient number of observations, takes the days on which all stations have observations during a three month's period, makes a daily average and from this a mean of the whole. Dividing this mean by the mean of each observatory for the same days during the three months a correcting-factor is received by which the daily reports can be multiplied to get thus corrected values. The corrected figures will then be averaged to obtain improved daily means.

Since most of the observatories possess plates extending back over many years, it is proposed to collect and publish the character figures for some years prior to 1928. In this way the material available for correlations with terrestrial phenomena could be much increased in a short time. First steps to gather this material are already made. Of course every care will be taken to improve the character numbers and to avoid too great differences between corresponding numbers.

As regards the relationships between spot-activity and terrestrial phenomena a new attempt is being made at our observatory to examine the influence of the position of the spot-groups on the sun's disc, and, further, the influence of the state of development of the groups. For this purpose relative spot numbers have been formed for the period 1911-1930 for an east and west central zone of 30° extension in longitude, for an east and west middle-zone from meridian 30° to 70°, and two limb-zones of 20° extension in longitude. These numbers are already calculated. To examine the influence of the state of development the groups should be divided into 4-5 types of development. The daily spot-number should be determined for each type-category for the whole sun and if necessary also for each zone. The material will be ready for discussion in 4-5 months' time.

LES PARASITES ATMOSPHÉRIQUES ET L'INFLUENCE SOLAIRE

par Robert Bureau.

Variation diurne des parasites atmosphériques - Le caractère le plus frappant des parasites atmosphériques est la régularité de leur variation diurne. Il est peu de phénomènes naturels qui en accusent une si vigoureuse, c'est le symptôme d'une influence solaire puissante. J'ai signalé à plusieurs reprises (1) que cette variation diurne était caractérisée par deux maxima principaux, l'un de nuit, l'autre d'après-midi; le premier est observé en toutes saisons, le second seulement d'avril à septembre inclus. Ce phénomène est général. Il a été signalé également par Watson Watt en Angleterre (2), Schindelhauer en Allemagne (3), confirmé par J. Ranzi (4) en Italie, par Fuchs et Scholz (5) au Sonnblick, par Asakura et Fujiwara (6) au Japon et par beaucoup d'autres auteurs.

Les courbes moyennes mensuelles font elles aussi, ressortir la variation diurne avec une grande vigueur; l'aspect des courbes moyennes varie de mois en mois, le caractère propre à chaque mois et est principalement dû à l'importance relative des deux maxima et à la durée de la nuit (dont dépend l'étendue du maximum nocturne). Ce caractère mensuel se conserve d'une année à l'autre. A la régularité de la variation diurne, s'ajoute donc une grande régularité de la variation annuelle, ce qui est un autre symptôme de l'influence solaire (Fig. 1)

Les courbes quotidiennes d'atmosphériques présentent aux environs immédiats du lever et du coucher du soleil des variations brutales qui révèlent d'une manière frappante l'influence solaire:

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Au lever du soleil, chûte brutale qu'il est extrêmement rare de ne pas observer. Cette chûte prend souvent l'allure d'une véritable cassure (Fig. 2) On la constate en toutes saisons. Elle est beaucoup plus marquée sur les ondes d'une fréquence de l'ordre de 500 à 50 Kc/s (c'est à dire longueur d'onde de 600 à 6000 mètres) que sur les ondes d'une fréquence plus faible, 30 à 10 kc/s, (c'est à dire longueur d'onde de 10000 à 30000 mètres) (Fig. 3).

Les courbes dénotent, sauf dans les mois d'hiver, un minimum souvent très aigu au moment du coucher du soleil (Fig. 4) En hiver le coucher du soleil n'est accompagné d'aucun phénomène remarquable et régulier (Fig. 2).

L'étude de la direction des parasites atmosphériques révèle des variations diurnes, annuelles, et de latitude d'une régularité remarquable ainsi que l'ont montré Watson Watt (7) et Schindelhauer (8).

Cause probable de la répétition saissonière et diurne des mêmes phénomènes. L'action solaire est indubitable. Comment agit-elle? Voici les explications que je propose.

Les parasites atmosphériques sont la résultante de deux phénomènes: la perturbation électrique naturelle qui en est l'origine; la propagation des ondes qui en proviennent. L'activité solaire agit à la fois sur le premier phénomène, la source, et sur le second, le voyage de l'onde. Mais sur l'un et l'autre elle n'agit ni de la même manière, ni dans le même délai. C'est sur ce point que je voudrais particulièrement attirer l'attention.

L'action la plus immédiate, celle où le délai est le moindre, où la 'constante de temps' de l'intermédiaire est la plus faible, c'est l'action sur la propagation. Il semble bien aujourd'hui que la plupart des auteurs en viennent, ou en reviennent, à attribuer à cette action la responsabilité du maximum nocturne. Si l'on reçoit plus d'atmosphériques la nuit que le jour, ce n'est pas qu'il y ait une production accrue des atmosphériques dans les heures de nuit, mais qu'on reçoit des atmosphériques venant de beaucoup plus loin. Le rayonnement solaire agit en défavorisant la propagation des ondes provenant de sources lointaines, par suite de son action ionisante sur les très hautes couches de l'atmosphère. Le fait que le maximum de nuit soit beaucoup moins marqué sur 2500 m que sur 6000 m est un argument en faveur de cette explication. Elle nous paraît beaucoup plus acceptable que celle, émise à diverses reprises (de Groot, Schindelhauer) d'atmosphériques naissant dans les couches ionisées par suite d'une action cosmique.

Le maximum d'après midi, observable en toutes saisons dans les régions tropicales, dans les saisons chaudes des régions tempérées est, lui, un effet indubitable d'un maximum des sources. Il a été souvent rapproché du maximum des orages. Il est en fait d'autant plus accentué que la situation est plus orageuse. Nous ne discuterons pas ici la question de savoir si les orages sont la seule cause des atmosphériques d'après-midi. Il suffit de signaler que les sources qui le provoquent semblent en général réparties dans un rayon de quelques centaines de km. seulement comme le montrent à la fois les statistiques (Austin, Proc. Inst. Radio. Eng. Octobre 1927 pp. 837-842) et l'étude des cas individuels et de rappeler qu'elles correspondent à un maximum des mouvements de convection de l'air provoqués par le rayonnement solaire et l'échauffement des basses couches de l'atmosphère. Ce sont les mêmes mouvements de convection qui font naître les cumulus, les cumulo-nimbus, les orages, les tornades.

Le maximum de l'ensemble des phénomènes énumérés ci-dessus, a lieu, comme le maximum des atmosphériques, vers 15 ou 16 heures. La 'constante de temps' est de quelques heures, alors que

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pour la propagation elle était de quelques minutes. Ainsi s'explique la forme en général rectangulaire et aux brusques contours du maximum nocturne et la forme triangulaire et souvent à contours arrondis du maximum d'après midi (Fig. 5).

En résumé, le maximum d'après midi a pour origine une action calorifique du rayonnement solaire sur les basses couches de l'atmosphère; le maximum de nuit est une conséquence de l'action électrique et ionisante de ce rayonnement sur les couches les plus hautes de l'atmosphère.

Dans les deux cas, ce ne sont vraisemblablement pas les mêmes portions du rayonnement solaire qui agissent. Et de plus elles font sentir leur action avec des retards différents.

Réaction de la troposphère. Phénomènes apériodiques. Quelle que soit la régularité de la variation diurne, on ne saurait négliger les variations, parfois énormes, observées d'un jour à l'autre et aussi d'une région à une autre.

Le maximum nocturne subit de grandes variations. Le maximum d'après midi de plus grandes encore. L'on constate enfin certains jours de très hautes valeurs des courbes aux heures habituelles des minima.

Dans ces phénomènes apériodiques, comme dans les phénomènes périodiques, il convient de faire la part des sources et celle de la propagation. Mais avant de chercher à faire ce partage, il nous fait bien constater qu'une relation étroite semble exister entre les phénomènes météorologiques de la troposphère et toutes les variations apériodiques des atmosphériques. Nous avons signalé plus haut que le maximum d'après midi est d'autant plus accentué que la situation est plus orageuse. De même la valeur du maximum nocturne dépend de l'origine et de la stabilité des masses d'air en altitude. L'arrivée d'une masse épaisse d'air polaire frais est accompagnée d'une recrudescence du maximum nocturne. L'arrivée d'air tropical en altitude semble entrainer chaque fois un affaissement du maximum nocturne (9).

Cette constatation nous amène à rechercher comment les grands mouvements de la troposphère (qui, en dernière analyse puisent leur énergie dans le rayonnement solaire, bien qu'avec des retards extrêmement longs, de l'ordre de jours, de mois et d'années) agissent, d'une part sur la répartition et l'énergie des sources, d'autre part sur la propagation des ondes.

(a) Action des mouvements de la troposphère sur les sources d'atmosphériques. Les mouvements de convection évoqués plus haut à l'occasion du maximum d'après midi ne dépendent pas seulement du rayonnement solaire et de la température mais également de la structure thermique verticale de l'atmosphère, structure très variable suivant l'origine des masses d'air. Il en résulte que la répartition des mouvements de convection n'est pas une simple fonction de la latitude, (ce qui entrainerait une origine tropicale de l'ensemble des atmosphériques). Elle est avant tout la conséquence des grands transports de masses d'air polaire vers l'équateur, de masses tropicales vers le pôle. Par suite de ces transports de masses d'air, non seulement les centres orageux (ou mieux les zones où la convection d'après midi prend de grandes valeurs) naissent, se développent et disparaissent tour à tour, mais des zones de grande instabilité verticle (quelle que soit l'heure) se déplacent à la surface du globe dans les régions tempérées et y promènent des sources importantes d'atmosphériques. C'est ainsi que les fronts froids jouent un si grand rôle dans la répartition mondiale des sources d'atmosphériques.

(b) Action des mouvements de la troposphère sur la propagation. Il parait plus difficile d'expliquer l'action de la

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troposphère (couches d'air d'altitude inférieure à 10 kilomètres) sur la propagation qui dépend avant tout de l'état électrique de couches situées à 100 kilomètres d'altitude et davantage. Cette action paraît moins étonnante si on évoque certaines expériences relatives à la propagation des ondes et qui montrent que les grands phénomènes de la basse atmosphère retentissent aux plus grandes altitudes et paraissent bien ne pas épargner les couches ionisées dont la structure commende la propagation. Je rapelle en quelques mots comment je suis parvenu à cette dernière conclusion. Au cours d'expériences entreprises sur la propagation des ondes courtes (10), j'ai constaté que les zones de silence qui affectent dans la soirée la propagation d'ondes de 28 à 36 mètres étaient réduites de plus de moitié dans certaines directions quand, dans ces directions, s'observait une vigoureuse invasion d'air tropical; j'ai expliqué pourquoi l'influence atmosphérique sur la propagation ne pouvait être alors une influence directe de la troposphère ni même de la basse stratosphère et qu'il en fallait conclure qu'une modification profonde des couches ionisées accompagnait une invasion importante d'air tropical. Il est difficile d'admettre, ne serait-ce que par considération des énergies mises en jeu, que les modifications des couches ionisées provoquent les perturbations de la troposphère. Les couches ionisées subissent donc probablement, à deux reprises, l'effet du rayonnement solaire: une première fois action directe presque immédiate, une seconde fois et seulement par exception, action retardée et indirecte dûe à la réaction de certaines grandes perturbations de la troposphère.

Conclusion. - Les atmosphériques seraient donc d'après ce qui précède une image fidèle de l'action complexe du rayonnement solaire sur l'atmosphère terrestre. Les diverses portions du rayonnement agissent de manière distincte, et dans les délais très divers, sur l'atmosphère comme sur les atmosphériques. Mais il est probable que cette complexité ne rendra pas le phénomène indéchiffrable; pour le déchiffrer, il suffira d'étudier simultanément des enregistrements d'atmosphériques faits en différents points de la terre, sur diverses longueurs d'onde etc .....

Les propriétés extraordinaires des courbes d'atmosphériques, dont je n'ai fait qu'une énumération rapide et incomplète, doivent attirer l'attention de toute personne qui étudie les rapports entre les phénomènes solaires et les phénomènes terrestres.

(1) R. Bureau - C.R. 180, 1925, p. 529: Onde électrique 5, 1926, p. 301: C.R. 189, 1929, p. 1293.
(2) R.A. Watson Watt - Journ. inst. elect. eng. London 64, 1926, p. 596.
(3) F. Schindelhauer - C.R. Assoc. franç. Avanc. des Sciences, Le Hâvre, 1929, p. 300.
(4) J. Ranzi - Nuovo Cimento 5, 1928, p. 326. : Boll. d. Societa Eustachiana Camerino, 27, 1929.
(5) Fuchs et Scholz - Gerlands Beitr. z. Geophysik 27, 1930, p.176.
(6) Asakura et Fujiwara - Geophysical Magazine, Tokyo, 1; 1926-28, p. 233.
(7) R.A. Watson Watt - loc. cit.
(8) F. Schindelhauer - C.R. Ass. Franç. avanc des Sciences, Le Hâvre 1929, p. 300.
(9) R. Bureau - C.R. 178, 1924, p. 556: Onde électrique 8, 1929, p. 134.
(10) R. Bureau - La Météorologie 5, 1929, p. 395.

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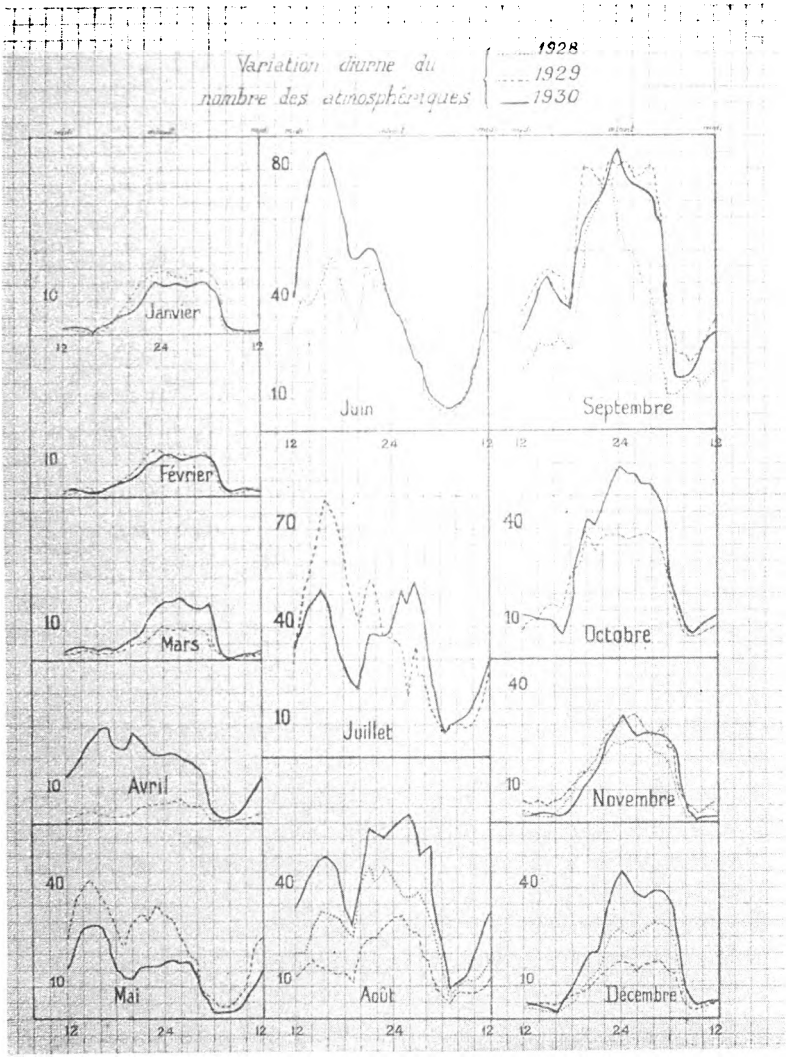

Fig. 1 Variations diurnes moyennes du nombre d'atmosphériques à Saint-Cyr (25 km Sud-Ouest de Paris) pour les différents mois en 1928, 1929 et 1930. Moyennes calculées d'après les courbes du radiocinémographe.

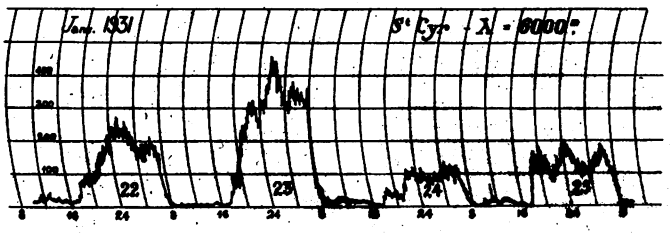

Fig. 2 Exemple de variation diurne d'hiver. Courbe de radiocinémographe de Saint-Cyr.

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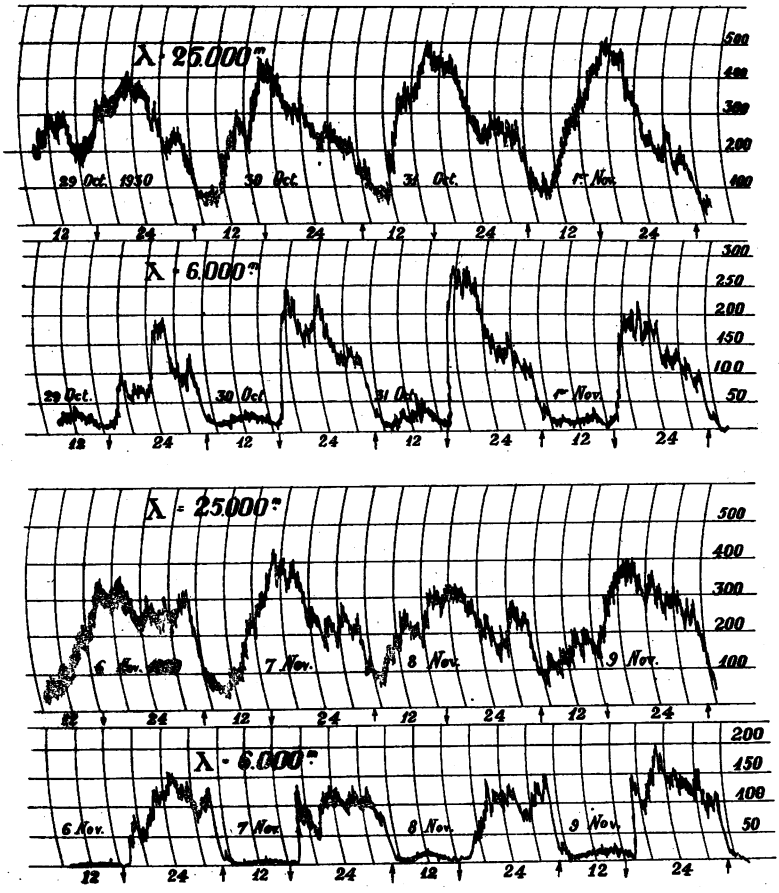

Fig. 3 Influence de la longueur d'onde sur la variation diurne du nombre d'atmosphériques. Enregistrements obtenus à Saint-Cyr du 29 octobre au 1er novembre et du 6 au 9 Novembre 1930 à l'aide du radiocinémographe.

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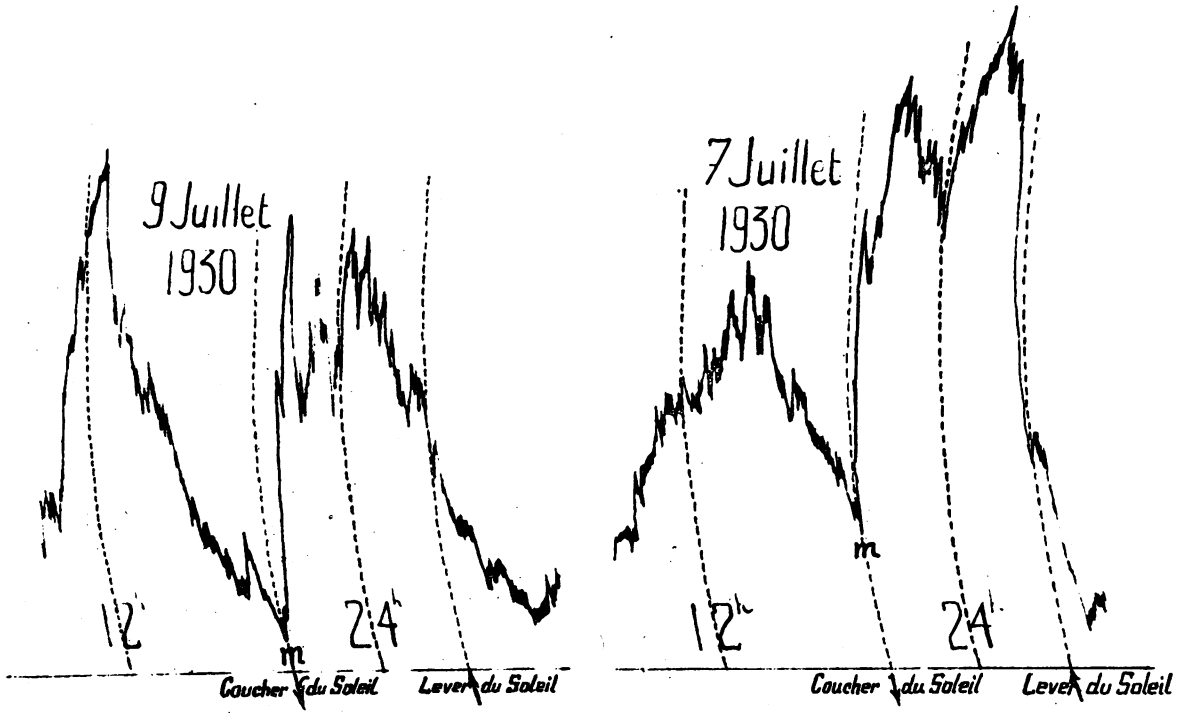

Fig. 4 Minimum d'été au coucher du soleil. Exemples du minimum observé au cours de la plupart des journées d'été - Enregistrements obtenus à Saint-Cyr les 7 et 9 juillet 1930 à l'aide du radiocinémographe.

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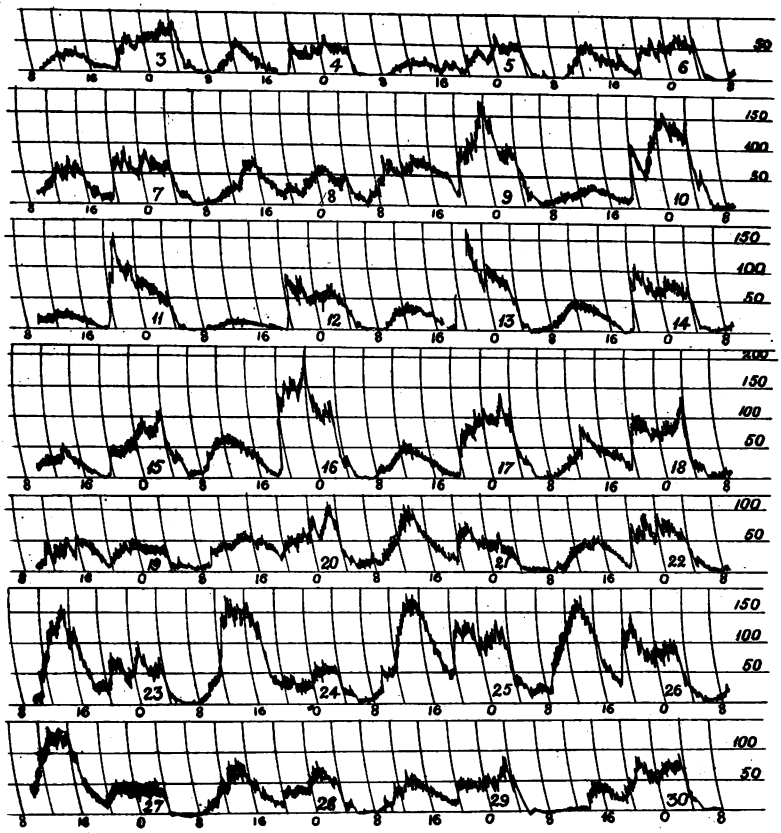

Fig. 5 Maximum d'après midi et Maximum de nuit. Exemple du mois de mai 1930 (3 au 30 mai) à Saint-Cyr. Enregistrements obtenus à l'aide du radiocinémographe.

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SOLAR INFLUENCES ON THE EARTH'S MAGNETISM AND ON THE UPPER ATMOSPHERE.

By S. Chapman.

The following is a brief account of some of the work done by the writer and his collaborators since the preparation of the last report of the Committee.

(a) Solar Streams of corpuscles in relation to magnetic disturbance.

The geometry of a stream of corpuscles issuing from the sun has been worked out, taking account of the solar rotation[x].

[x] Monthly Notices R.A.S., Vol. 89, p. 456, 1929.

In the same paper various physical questions relating to such streams were discussed, and, in particular, (1) the possibility of obtaining an observational test of the existence of such streams by the absorption lines which they would be expected to produce during magnetic storms if the earth is then enveloped in a stream extending between it and the sun; and (2) the depth to which the particles projected according to Milne's theory would penetrate the atmosphere; there still remains a serious difficulty in accounting for the penetration to heights as low as those, of about 80 km., at which aurorae have been measured by Stormer.

A re-investigation, with V. C. A. Ferraro, of the electrical state of solar streams of corpuscles (ibid. p. 470) confirmed the conclusion reached some years earlier by F. A. Lindemann that if the speed of the corpuscles is of the order 1000 km./sec., the streams must be neutral to a very high degree of accuracy when they are near the earth.

Ferraro has considered (ibid, vol. 91, pp. 174) the possible emission of solar streams of corpuscles from the sun which, while electrically neutral, could carry an electric current and exert a magnetic field: he concludes that any such current and field must be quite insignificant. Also (ibid, p. 184) he shows, on the basis of Kramer's theory of emission and absorption, that re-combination of ions, in ionized streams of corpuscles of any likely density, during their passage from the sun to the earth, is very small.

A preliminary note (Nature, 1930, July 26) on a new theory of magnetic storms, by Ferraro and the writer, attributes them to solar neutral ionized corpuscular streams, and outlines their mode of action. Further details will be published in 'Terrestrial Magnetism'.

A criticism (Monthly Notices, R.A.S., Geophysical Supp., vol. 2, 296, 1930) has been published of the theory by E. O. Hulburt and H. B. Maris that magnetic storms are due to ultra-violet radiation and not to solar corpuscles. Hulburt has consequently largely re-modelled his theory (Phys. Rev. vol. 36, p. 1560, 1930) but without meeting one of the chief objections, relating to the penetration of the corpuscles (which in his view are of terrestrial origin) that produce aurorae.

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(b) The Variability of the Solar Diurnal Magnetic Variation on quiet days.

With J. M. Stagg two papers relating to the irregular changes of range of the daily magnetic variation on very quiet days have been published (Proc. Roy. Soc. A, vol. 123, p. 27, 1929 and vol. 130, p. 668, 1931). The standard deviation of the daily ranges from their normal value are about 20 per cent., and show a distinct correlation at widely separated stations. This work is intended to provide a basis on which later a scheme of international magnetic classification of days may be based, independent of the now long-standing classification as regards magnetic activity.

(c) The Theory of the Solar Diurnal Magnetic Variation.

A new 'drift-current' theory of the solar diurnal magnetic variation has been published (Proc. Roy. Soc. A, 122, p. 369, 1929), but this will require modification because atmospheric drift-currents (and diamagnetism) in a gas in thermodynamic equilibrium now appear to be negligible (T. G. Cowling, Monthly Notices, vol. 90, p. 140, 1929). The re-construction of the theory must take account of the departure of the state of the atmosphere from thermodynamic equilibrium - a difficult problem not yet seriously attacked.

(d) Ionization of the Upper Atmosphere.

The first of a series of theoretical papers on upper-atmospheric ionization has been published (Proc. Phys. Soc. vol. 43, Pt.I. No. 236, pp. 26-45 1931). It deals with the daily and annual variation of the ionization, on certain simple hypotheses, at various heights, seasons and latitudes.

(e) The Variation of Atmospheric Ozone.

Three theoretical papers have been published on the mode of formation and disappearance of ozone, and also atomic oxygen, in the upper atmosphere. It is concluded that the observed annual variation of ozone, and the absence of any large daily variation, are not incompatible with the formation of the ozone by ultraviolet light (Mem. Roy. Meteor. Soc. vol.III, pp. 103-125, 1930). It has also been shown that the annual variation cannot be explained as due merely to increased thermal dissociation in summer in consequence of an annual summer maximum and winter minimum of temperature in the ozone layer (Phil. Mag. vol. X. pp. 345-352, 1930). It is shown that the proportion of ozone is likely to decrease above 50 km. height, while the molecular oxygen must be dissociated to atomic oxygen, the concentration of which must increase upwards from the level of the densest part of the ozone layer. (Phil. Mag. vol. X, pp. 369-383, 1930).

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RELATION OF WORLD WEATHER TO SOLAR RADIATION CHANGES

by H. Helm Clayton.

Latitude Effect.

In 1916 I began an investigation as to whether any relation existed between the day to day changes of solar radiation observed by the Smithsonian Institution and weather changes.[1] Daily observations of temperature and pressure were gathered from widely separated stations on the earth and these observed values were correlated with solar changes. The correlation coefficients were in some cases as high as 0.50 and they showed a distinct relation to latitude. Within the tropical belt of the earth, between 30° north and 30° south there was a distinct tendency for the temperature to rise and for the atmospheric pressure to fall with increased solar radiation. At latitudes between 30° and 50° in both hemispheres there was the opposite tendency, namely, for the temperature to fall and the pressure to rise. At latitudes about 60°, more especially over the oceans, another belt was found in which the temperature rose and pressure fell in the same sense as in the equatorial zone, but in a more marked degree. The latitude effect of solar radiation changes on the earth is shown in Fig. 1. where the shaded areas show increased temperature and decreased pressure and the white areas show decreased temperature and increased pressure.

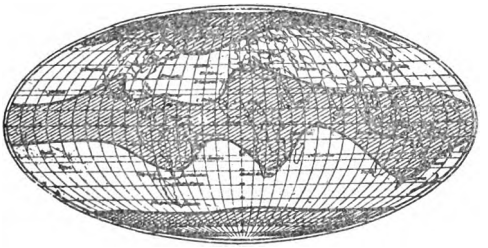

Fig.1. Zonal effect of increased solar activity. Shaded areas show regions where the pressure falls and the temperature rises with short period changes of solar radiation. Unshaded areas show regions where the reverse conditions occur.

In 1916 there were not a sufficient number of months of observation to make a detailed comparison of solar radiation by months with terrestrial temperature and pressure, but by 1920 it became evident that although solar radiation values are much more variable than sunspots they both showed a period of about eleven years in the same sense, that is, when sunspots were numerous solar radiation increased. For this reason it was thought probable that smoothed values of pressure and temperature would show significant correlations with sunspot numbers. Accordingly three year means of pressure were obtained for 81 stations scattered over the earth covering periods of 15 to 70 years. These smoothed values were correlated with sunspot numbers and they showed negative correlations exceeding 50 per cent in the tropics, positive correlations in middle latitudes and negative correlations again in high latitudes.[2].

Fig. 2. shows the areas and the lines of equal negative and positive correlation. The results agree with those found for short period changes in showing negative relations in the equatorial regions and positive relations in middle latitudes except over the northern part of the great oceans and the Lake Region of the United States. There were no data for stations north of about 65° of latitude.

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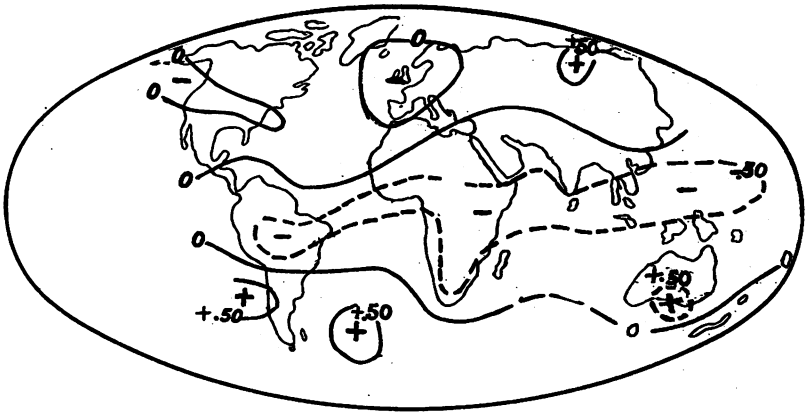

Fig. 2-Correlation between sunspots and 3-year means of atmospheric pressure.

Within the belts of decreased pressure there was increased rainfall; that is in the regions where the pressure varied inversely with solar radiation the rainfall varied directly with radiation.[3] On the other hand where the pressure increased the rainfall diminished. This result is seen by a comparison with Fig. 3, where shaded areas show an excess of rainfall at the time of sunspot maximum and clear spaces a deficiency, except in high latitudes and over the Pacific ocean where data were missing. The excess and deficiency were computed as per centages of normal values and lines are drawn for each 10 per cent.

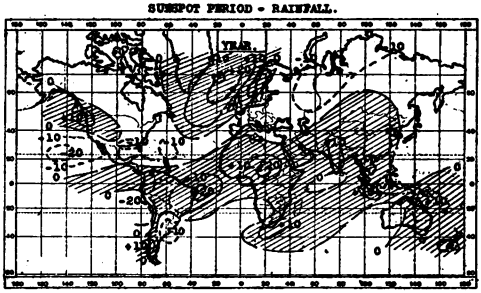

FIG. 3. Shaded areas show an excess of rainfall at the time of sun-spot maximum. Broken lines indicate a deficiency of rainfall at the time of sun-spot maximum. Figures at end of line give percentages of excess or deficiency of rainfall over that at minimum spots.

The temperature correlations were less definite. There were some areas of increased temperature with increased solar radiation, chiefly in latitudes north of 60°: over most of the temperate and equatorial zones the temperature decreased with increased solar radiation. The decrease of temperature over most of the earth with increase of solar activity agrees with the finding of Köppen many years ago. The decrease of surface temperature in the equatorial

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zone appears to be the result of increased cloudiness, increased rainfall and increased flow of air from higher latitudes, all tending to produce lower surface temperatures. The decrease of pressure over the equatorial zone with increase of solar radiation implies an increase of temperature at some level of the atmosphere, probably above the lower cloud stratum.

The publications of World Weather Records [4] by the Smithsonian Institution gave an opportunity to study the effects of changes in solar activity on the monthly means of pressure and temperature. The Northern Hemisphere was divided into zones of 10° of latitude and 20° of longitude and the mean atmospheric pressure obtained for each zone. The mean pressure by zones of latitude when solar radiation was high showed a distinct contrast with the mean values when solar radiation was low. In the first case, pressure was lower than normal from the equator to about 35° north, it was higher than normal between 50° and 60° north, and lower again north of latitude 65°. The reverse was true with low solar radiation [5]. The results are shown plotted in Fig. 4. for each 10° of latitude from the equator across the pole.

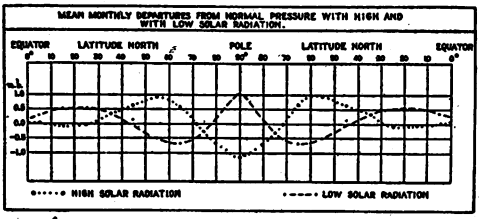

FIG. 4. Mean monthly departures from normal pressure with high and with low solar radiation.

In Fig. 5. the departures from normal shown in Fig. 4. are added to the normal distribution of pressure with latitude which is indicated by the continuous line. The mean latitude distribution of pressure with high solar radiation is shown by the dotted line and the mean latitude distribution with low solar radiation is shown by the broken line. It is seen from the plot, (1) that the pressure gradients of the atmosphere are increased with increased solar radiation and (2) that the belt of maximum pressure near the 35th parallel moves north of its normal position with increase of solar radiation.

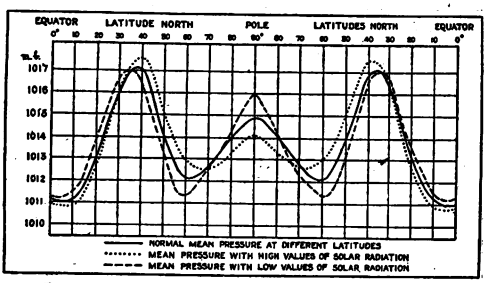

FIG. 5. Mean pressure at different latitudes with different solar conditions.

Land and Ocean Effect.

The longitude differences in pressure with changes in solar radiation indicate a marked land and ocean influence on the results, which reverses with the season. With increase of solar radiation the atmospheric pressure increases over land in winter and diminishes in summer [6]. The reverse condition occurs over the

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ocean. The relations thus found for latitude and for land-ocean areas are in the nature of standing waves which vary directly with variations in solar radiation.

Moving Waves of Weather.

The disentangling of solar influences is rendered very difficult by the discovery that following oscillations in intensity of solar radiation something in the nature of pressure and temperature waves are sent out from certain centers of action, more especially from the polar areas. These moving waves are the chief cause of weather changes. They progress with a velocity proportional to the length of the oscillation of the solar pulsation, that is, oscillations of short duration produce waves which move rapidly, and oscillations of long duration produce waves which move slowly [7]. The combined effect is the complex condition found on our weather maps.

Solar and Weather cycles.

When solar radiation values are analyzed from daily observations, from ten day means, from monthly means or from annual means they show oscillations of a periodic nature with increasing length of period with increase in the length of the time interval used in the analysis. The annual solar radiation means show an eleven year period, but it is not the dominating period as in the case of sunspots. There are found instead marked oscillations of a few days in length, other oscillations of about 30 weeks, of about 5 months, of 8 months, of 11 months, of 22-28 months, 45 months, etc. which have amplitudes approximately as great as that of the eleven year period.

Terrestrial temperature and pressure show similar oscillations, and it is of importance to note that these terrestrial changes show a similarity to solar radiation changes and not to the sunspot curve.

The shorter periods found approximate to fractions of the 11.25 year sunspot period or the double sunspot period of 22.5 years. It is hence assumed that they are harmonics of this longer period. A computation was made of the amplitudes and phase angles of the primary period and of its harmonics for the interval 1917 to 1928, and the following results were obtained [8]:-

TABLE 1 - Harmonic Terms for 11¼-Year Period in Sun Spots and Solar Radiation.

Sun-spot numbers.		Solar radiation.	
Epoch 1917.5	Amplitude in numbers.	Epoch 1917.5	Amplitude in calories.
$A_1 = 104^\circ$	$a_1 = 35.3$	$A_1 = 64^\circ$	$a_1 = .009$
$A_2 = 274^\circ$	$a_2 = 7.9$	$A_2 = 238^\circ$	$a_2 = .004$
$A_3 = 305^\circ$	$a_3 = 10.6$	$A_3 = 50^\circ$	$a_3 = .008$
$A_4 = 333^\circ$	$a_4 = 6.0$	$A_4 = 339^\circ$	$a_4 = .005$

These results show that in a general way the oscillations in the number of sunspots and in the intensity of solar radiation are in the same phase, that is when one increases the other increases; but the amplitudes of the changes are very different. The amplitude of the primary oscillation, a_1, in the sunspots (the 11.25 year period) is decidedly predominant while in the solar radiation the

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harmonics of $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{1}{4}$ of 11.25 years, namely a_2, a_3, and a_4 are almost as large as a_1.

The atmospheric pressure at nine tropical stations was analyzed in the same way, using the mean of all the stations, and the results given in Table 2 were obtained.[9] This comparison indicates that the 11.25 pressure period in the tropics is inverted in phase to sunspots and solar radiation, while the relative value of the amplitudes of the harmonics to the primary is similar to that in the case of solar radiation and not in sunspots.

TABLE 2. - Harmonic Terms for $11\frac{1}{4}$-Year Period in Pressure. 1890-1913. Mean Pressure of 9 Equatorial Stations. Epoch 1895.0 = 1917.5

A_1	= 325°	a_1	= 0.36 mb.
A_2	= 29°	a_2	= 0.32 mb.
A_3	= 265°	a_3	= 0.25 mb.
A_4	= 150°	a_4	= 0.35 mb.

In order to compare the harmonic terms of the 11.25 year period in pressure in equatorial regions with those in other latitudes, the mean pressure was obtained for each ten degrees of latitude for each year from 1890 to 1913. From the data thus obtained harmonic terms were computed for each zone of latitude. The amplitudes of the primary and of the different harmonics are given in Table 3. The striking facts brought out are - (1) The amplitudes of the periodic terms increase greatly in high latitudes and (2) the amplitudes of the smaller subharmonics in high latitudes are much greater than the amplitude of the period of 11.25 years. This last finding is of importance because it shows that the shorter periods are of much more importance in the meteorology of high latitudes than is the period of about eleven years. These meteorological and solar periods are believed to be harmonics of much longer solar periods.

TABLE 3. - Amplitudes of the Harmonics of a 22.6-Year Period in Pressure.

Zones of latitude.	No. of sta.	a_2 11.3 yr.	a_3 7.54 yr.	a_4 5.65 yr.	a_6 3.77 yr.	a_8 2.83 yr.	a_{24} 11.3 mo.	a_{48} 5.7 mo.	a_{72} 3.8 mo.
70°-80°N	2	0.60mb	0.65mb	0.94mb	0.92mb	1.12mb	2.40mb	2.50mb	3.75mb.
60°-70°	14	0.59	0.61	0.77	0.88	0.86	2.09	2.78	2.31
50°-60°	21	0.34	0.38	0.46	0.61	0.76	1.32	1.60	1.28
40°-50°	25	0.32	0.42	0.43	0.45	0.51	1.22	1.10	1.23
30°-40°	30	0.24	0.33	0.40	0.31	0.31	0.67	1.02	0.88
20°-30°	13	0.36	0.21	0.29	0.24	0.23	0.62	0.63	0.53
10°-20°	15	0.42	0.25	0.35	0.21	0.33	0.42	0.45	0.40
0°-10°	6	0.36	0.27	0.32	0.25	0.35	0.39	0.25	0.38

NOTE. - In computing the harmonics in Table 3 the means of three or of four periods were used in each case except the case of a_2 where two periods were used. The observed values from which a_2 were computed covered the entire interval of 22.6 years, while the values from which a_{72} were computed covered only about one twenty-fourth of this interval.

The increase in amplitude with increase of latitude is evidently caused by the earth's rotation on its axis. Why the amplitudes of the smaller harmonics should increase much more than the amplitude of the primary period is not clear.

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The solar and atmospheric changes do not repeat themselves always after a period of 11.25 years and so far as known after no other interval of time, This fact appears to indicate that there is no continuous periodicity in these conditions. An analysis of the data into individual periods and into overlapping groups of periods shows that there are periods or cycles, but that these periods vary in amplitude and occasionally reverse in phase.[10] The reason for this is not known.

A good example of a meteorological period is given by Dr.O. v. Schubert of Berlin.[11] Dr. Schubert was investigating a period of about three years in pressure which has attracted the attention of Braak, Verlage, Nansen, Kidson and others. Plotting annual deviations of pressure from normal for numerous stations of the world, mostly land stations, he counted the number of stations showing maxima each year and the number showing minima. The results show a distinct tendency for excess of maxima to occur about every third year. From 1888 to 1900 this period is very close to a period of about 2.813 years or one fourth of a sunspot period.

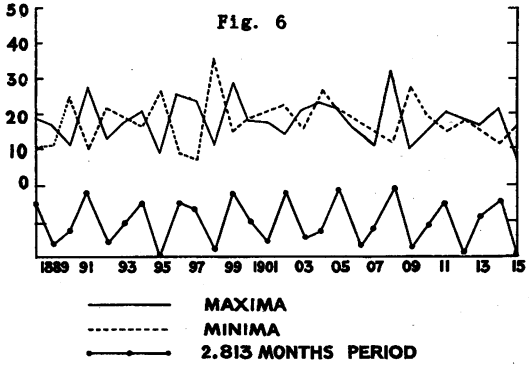

Fig. 6

A copy of the plot given by Dr. Schubert is given in Fig.6: in the lower curve in this figure is added the curve of sine values of a 2.813 years period having a minimum value of unity in the year 1895. The sine values show a fair agreement with the observed values except between the years 1900 and 1905. The questions which arise are, was this break in the sequence due to the interference of other periods of different length, to a break in the solar periods[12], or to a displacement of the centers of oscillation on the earth's surface such as I found in a study of a 25 months period[13]?

References.

(1) Effects of Short Period Variations of Solar Radiation on the Earth's Atmosphere. Smith. Misc.Coll. Vol.68,No.3., May, 1917.
(2) Solar Activity and Long Period Weather Changes. Smith. Misc. Coll., Vol.78, No.4., p.40, Sept. 1926.
(3) Solar Radiation and Weather or Forecasting from Observations of the Sun. Smith. Misc. Coll., Vol.77, No.6., p.39, June 1925.
(4) World Weather Record. Smith. Misc. Coll., Vol.79, 1927.
(5) The Atmosphere and the Sun. Smith. Misc. Coll., Vol.82, No.7. p.10, June 1930.
(6) World Weather. The Macmillan Co., New York, 1923, pp.242 & 303.
(7) World Weather. l.c. pp.111-125 and pp.135-136. Also Atmosphere and the Sun. l.c.pp.18-28.
(8), (9), (10) The Atmosphere and the Sun. l.c. pp. 33, 34, 42, 43.
(11) Die dreijährige Luftdruckwelle, von O.v. Schubert, Ver.Geo.Inst. d.Un.Leipzig, 1928.
(12) The Atmosphere and the Sun. l.c. pp.42 and 43.
(13) Solar Activity and Long Period Weather Changes. L.c. p.48.

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SUR L'OBSERVATION DES PHÉNOMÈNES ÉRUPTIFS DANS LA CHROMOSPHERE SOLAIRE ET LEURS RELATIONS AVEC LES ORAGES MAGNÉTIQUES.

par L. d'Azambuja.

Par leur aspect, aussi bien que par les régions de l'astre où ils apparaissent, les phénomènes éruptifs décelés à l'aide du spectrohéliographe dans la chromosphère solaire, appartiennent à deux catégories bien distinctes.

Les premiers ont leur siège dans les plages faculaires, c'est-à-dire dans les groupes compacts de flocculi brillants dont la forme générale et la position coïncident avec les facules de la surface. Ils se manifestent par l'apparition presque soudaine, dans une région plus ou moins étendue de la plage, d'une masse aux contours changeants qui, après avoir attient un éclat parfois tout à fait exceptionnel, reprend en quelques heures, ou même en un temps plus court, l'intensité des régions voisines. L'éruption, comme on peut le voir lorsqu'elle se produit près du bord, est presque toujours accompagnée de jets protubérantiels intenses et peu élevés, la masse principale restant localisée au niveau de la chromosphère.

Le second type d'éruptions s'observe dans les protubérances quiescentes. Celles-ci, comme l'on sait, ne subissent habituellement que des variations assez lentes, tout au moins quand on considère leurs formes générales et non les petits détails de leur structure. On en signale assez souvent qui, après une première apparition à un bord du disque, se retrouvent sans modifications sensibles lorsque la rotation les amène au bord oppose, et qui se montrent encore apres une ou plusieurs révolutions complètes de l'astre. Mais il arrive parfois que, après une longue période de calme, ces protubérances s'animent brusquement. En quelques heures, leurs formes se modifient profondément, leur hauteur croît et attaint, dans certains cas, une valeur énorme, de l'ordre du rayon solaire; puis elles s'évanouissent ou ne conservent que les parties les plus basses et les plus intenses de leur structure primitive.

Par leur brièveté même, ces phénomènes échappent souvent à la vigilance des observateurs et le nombre de cas qui ont pu être suivis dans leur complet développement est encore assez restreint. Il est très remarquable toutefois que presque toutes les éruptions du premier type signalées jusqu'ici aient coïncide avec des orages magnétiques intenses[1].

Pour les éruptions dans les protubérances, auxquelles cette Note est plus spécialement consacrée, la question est moins avancée.

Lorsqu'elles se produisent extérieurement au bord solaire, le spectrohéliographe les décèle aussi aisément que

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(1) Voir en particulier à ce sujet:
L. d'Azambuja: Revue des travaux sur le Soleil en 1926 - L'Astronomie, t. 41, 1927, p. 178.
G. Abetti: Sulle relazioni fra le eruzioni solari e le tempeste magnetiche terrestri - Atti della R. Accademia dei Lincei, 6me série, t. 5, 1927, p. 721:
et une Note de ce dernier auteur parue dans le second rapport de la Commission pour l'étude des relations entre les phénomènes solaires et terrestres, 1929, p. 9.

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les éruptions des plages faculaires; mais la direction dans laquelle se déplace la vapeur est alors à peu près perpendiculaire à celle de la Terre et il y a peu de chances pour que celle-ci soit atteinte par une émission corpusculaire issue du phénomène. En fait, croyons-nous, aucune coïncidence précise n'a jamais été signalée dans ce cas avec les orages magnétiques.

Quand les éruptions se produisent dans des protubérances en projection sur le disque, les circonstances sont plus favorables à une action sur la Terre. Malheureusement, l'observation devient beaucoup plus délicate. En effet, la composante radiale de la vitesse avec laquelle se propage la vapeur est alors prépondérante et la raie protubérantielle, soumise au déplacement Doppler-Fizeau, cesse souvent d'être contenue dans la fente sélectrice du spectrohéliographe. Celui-ci laisse ainsi échapper la phase la plus intéressante du phénomène. H.Deslandres, qui a le premier attiré l'attention sur cet inconvénient a proposé, pour y remédier, d'employer simultanément son spectro-enregistreur des vitesses. Cette méthode n'a peut-être plus le même intérêt depuis la réalisation par G.-E. Hale, du spectrohélioscope. Elle conserve néanmoins l'avantage du document photographique qui peut être étudié à loisir sur l'observation visuelle. D'ailleurs, elle a fourni aux observateurs de Meudon l'occasion de déceler et de suivre plusieurs éruptions protubérantielles en projection sur le disque. Voici, brièvement résumées, les trois plus caractéristiques[1]. Le dernière a permis d'estimer de manière approximative, non seulement la direction de l'espace dans laquelle se déplaçait la masse de vapeur, mais aussi la hauteur qu'avait atteinte celle-ci avant de cesser d'absorber.

1°; Le 11 avril 1910, à 8^h0^m (T.U.), les images de la raie K: fournies par la spectro-enregistreur, montraient un aspect inaccoutumé dans une region du quadrant Sud-Est ou le spectrohéliographe ne révélait aucun detail marquant. La composante médiane K_3, qui conservait sa position et son intensité habituelles, était doublée, à distance variable et surtout du côté violet, par une second raie sombre se projetant sur K_1. Tout se passait comme si, la couche K_3 restant a peu près dans son état ordinaire, une grande masse de gaz au-dessus, s'élevait irrégulièrement à de grandes vitesses. Le phénomène dura quelques heures, puis toue trace de perturbation disparut.

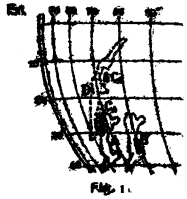

Fig. 1.

1. La description complète de ces phénomènes a été donnée dans les deux Notes suivantes:
H. DESLANDRES, L. d'AZAMBUJA et V. BURSON: Sur un filament extraordinaire. - Comptes rendue de l'Académie des Sciences, t. 150, 1910, p. 1635.
L. d'AZAMBUJA: Observations de masses mobiles de vapeur absorbante à de grandes hauteurs au-dessus de la surface solaire. Rapprochement avec les protubérances élevées, à évolution rapide. - Comptes rendus de l'Académie des Sciences, t. 180, 1925, p.47.

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2°; Le 25 mai 1920, à $9^h\ 48^m$, une belle protubérance, calme jusque-là, occupait la position marquée A sur la fig. 1. Le 26, à $8^h\ 15^m$, alors qu'elle aurait dû se trouver en B si elle avait suivi les lois habituelles de la rotation et de la perspective, elle avait à peu près disparu sur l'image K_3; seules, quelques traces étaient encore visibles en C_1 C_2 (régions hachurées). Mais l'épreuve du spectro-enregistreur permettait de la retrouver en D, très déformée et animée dans son ensemble d'une vitesse radiale de 30 kilomètres-seconde, environ, vers l'observateur. A $9^h\ 20^m$, une nouvelle épreuve ne décelait plus aucune trace du phénomène. En projection, le chemin parcouru par la protubérance avait été considérable (200.000 kilomètres environ). Les vitesses radiales observées montrent que, dans le même temps, elle s'écartait rapidement de la chromosphère.

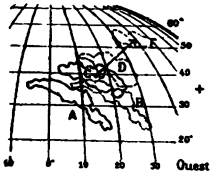

Fig. 1.

3°: Le 8 juin 1920, une protubérance très marquée en absorption et stable depuis son apparition au bord Est occupait, à $7^h\ 58^m$, la position A (Fig.2). Le 9 juin, à $8^h\ 6^m$, elle aurait dû se trouver en B. L'image K_3 la montrait en C, élargie et privée de sa partie Sud-Ouest. Peu après, elle cessait d'être visible pour le spectrohéliographe. Les épreuves du spectro-enregistreur la montraient successivement en D (à $9^h\ 0^m$), puis en E (à $9^h\ 40^m$). L'épreuve suivante (à $10^h\ 37^m$) n'en offrait plus aucune trace.

En D et en E, la vitesse radiale de l'ensemble était de 25 kilomètres-seconde environ, vers l'observateur. Si l'on admet ce qui est vraisemblable, qu'elle a gardé sensiblement cette valeur entre $8^h\ 6^m$ et $9^h\ 40^m$, et que l'on compose le déplacement qui s'en déduit avec le mouvement horizontal observé, indiqué par la flèche sur la figure 2, on en conclut que la protubérance a pu atteindre, à partir de la position C, déjà fort élevée probablement, une hauteur de 225.000 kilomètres, soit un sixième du diamètre solaire.

Aucune de ces éruptions n'a coïncidé avec une agitation notable de l'aiguille aimantée. Il n'y a pas lieu d'en être trop surpris car elles se sont produites dans des régions du disque assez éloignées du centre et la direction dans laquelle se déplaçaient les vapeurs, dans les cas où elle a pu être estimée, était très oblique par rapport à la Terre. Il faut signaler, à ce propos, le rapprochement fait par H. Deslandres[1]. entre le grand orage magnétique du 25 september 1909 et la disparition rapide, entre le 24 et le 25, d'une protubérance importante en projection sur le disque. Les phases de la disparition n'ont pu être observées, mais elles se sont sans doute déroulées d'une

1. H. DESLANDRES: Orages magnétique du 25 september 1909 et phénomènes solaires connexes. Vérification des théories proposées. - Comptes rendus de l'Académie des Sciences, t. 150, 1910, p. 65. Voir aussi une Note du même auteur parue dans le second rapport de la Commission pour l'étude des relations entre les phénomènes solaires et terrestres, p. 41.

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manière analogue à celle décrite ci-dessus. Ou, la protubérance était plus près du centre du disque que dans les cas précédents.

Il semble donc qu'une observation plus continue de ces phénomènes, surtout lorsqu'ils se produisent dans la région centrale de l'astre, soit susceptible de fournir des résultats intéressants. L'utilisation de plus en plus fréquente du spectrohélioscope doit être recommandée dans ce but, sans qu'il y ait lieu pour cela de négliger l'emploi combiné du spectrohéliographe et du spectro-enregistreur.

Il faut, d'autre part, que l'annonce des éruptions observées soit diffusée le plus rapidement possible. Cette partie du programme a reçu récemment un commencement de réalisation: depuis le 1er décembre 1928, sur l'initiative de l'Union internationale de Radiotélégraphie scientifique, un Bulletin d'information, contenant diverses indications sur l'état de l'activité solaire et, le cas échéant, sur les manifestations exceptionelles de cette activité, est rédigé d'après les observations effectuées à Meudon et radiophoné chaque jour par le poste de la Tour Eiffel. Un résumé de ce même Bulletin est radiotélégraphié par les postes de Bordeaux-Lafayette et d'Issy-les-Moulineaux.

Dans un order d'idées analogue, rappelons que le dernier Congrès de l'Union astronomique internationale, réuni à Leyde en juillet 1928, après avoir décidé que des nombres-indices de l'activité solaire seraient désormais publiés dans un Bulletin trimestriel[1], a prescrit aux divers Observatoires participants[2] d'indiquer par une Note spéciale les changements rapides qui pourraient se manifester dans les plages faculaires ou dans les protubérances en projection sur le disque solaire.

Mars, 1931.

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1. Bulletin for Character Figures of Solar Phenomena, publié par M. W. Brunner, Directeur de l'Observatoire fédéral de Zurich.

2. Pour les phénomènes chromosphériques, ces Observatoires sont les suivants: Arcetri-Firenze, Cambridge, Coimbra, del Ebro, Evershed-Ewhurst, Kodaikanal, Meudon-Paris, Mount Wilson, Tokyo.

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RELATIONS ENTRE LE SOLEIL ET LA TERRE.

par H. Deslandres.

Je puis reprendre en 1931 les termes mêmes de mon rapport de 1925 et aussi de 1929.

Il importe de réaliser le mieux possible la continuité dans l'étude du Soleil, par une coopération bien ordonnée, entre les observatoires actuels, et par la création d'observatoires nouveaux. La comparaison avec les variations du champ magnétique terrestre sera rendue ainsi plus utile.

Le rayonnement corpusculaire du Soleil, pendant longtemps négligé, a une importance très grande, au moins aussi grande que le rayonnement ondulatoire. Il est absorbé par la matière beaucoup plus fortement que le rayonnement du type lumineux; en fait il est absorbé surtout dans le Soleil lui-même et est la cause principale des phénomènes singuliers (taches, facules, protubérances, etc.) observés journellement dans le Soleil. Une petite partie seulement de ce rayonnement corpusculaire arrive jusqu à la terre, et produit les aurores boréales et les variations du champ magnétique terrestre. C'est à ce rayonnement que l'on doit rapporter surtout la formation de la couche d'Heaviside qui, dans notre atmosphère, correspond au quatrième état de la matière de Crookes, et est formée des particules électrisées les plus petites, ions et électrons.

La couche d'Heaviside, qui reçoit directement les deux rayonnements du Soleil, subit plus que les autres couches terrestres, les variations solaires, et j'estime, comme plusieurs hommes de science français, que l'on doit chercher dans cette couche électrisée la cause première des grands troubles de notre atmosphère.

Il faut donc reconnaitre et suivre journellement la couche d'Heaviside et ses variations; ce qui est à priori difficile. Mais la telegraphie sans fil fournit des indications précieuses; elle donne aisément la hauteur de la partie inférieure de la couche et il est permis d'espérer que l'on aura un jour les moyens d'envoyer des appareils enregistreurs a de très grandes altitudes. On a préconisé l'emploi de la fusée, déjà utilisée par l'artillerie, et qui, bien réglée, donne une solution du problème.

La prévision du temps, jusqu'ici très insuffisante, aura une base solide lorsque l'on connaitra chaque jour l'état de l'atmosphère basse et aussi de la couche d'Heaviside sur la terre entiere.

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REPORT ON MEASUREMENTS OF ATMOSPHERIC OZONE.

by G.M.B. Dobson.

Since the last report was written in April 1928, two main researches into the distribution of ozone have been completed: these refer to (1) the distribution of ozone in Europe associated with different types of pressure distribution and (2) the distribution of ozone over the world during the different seasons of the year. The results of some four years' work on these questions is best summarised in Figures 1 to 4, which are reproduced by permission of the Council from the Proceedings of the Royal Society (A, vol. 122, 1929, p. 469 and vol. 129, 1930, pp.417, 418). As the results at most stations have not extended over much more than twelve months, one must not regard them as being accurate in details. but it is thought while further observations will probably make small changes the broad outlines are correct.

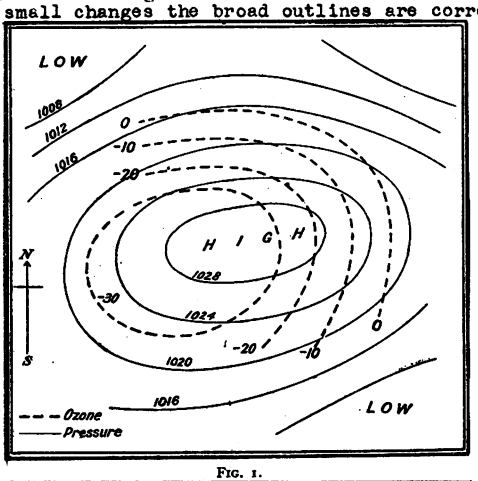

FIG. 1.

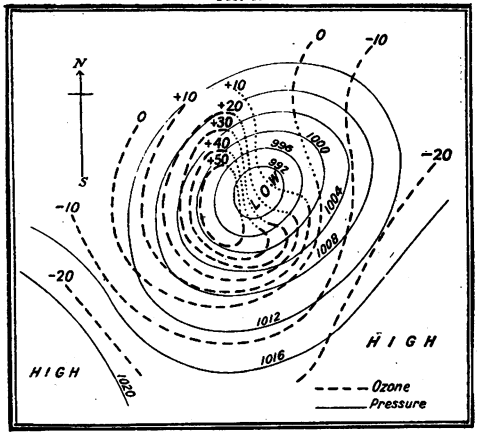

FIG. 2.

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A further study of the height of the ozone layer in conjunction with Dr. Götz at Arosa indicated that the average height is about 45 km. to 50 km., and not under 40 km. as previously reported. There seems to be no change in the average height of the layer either with the season of the year or with the pressure conditions.

M. Buisson has measured the absorption of radiation of wave-length between 5780 Å and 2482 Å by the lower atmosphere with a view to determining the amount of ozone near the ground. While there is appreciable absorption of the short wave lengths, it is doubtful how much of it is due to ozone, since the change of absorption with wave-length does not agree well with the ozone absorption curve. In any case there cannot be 10 per cent of the ozone in the lower layers which there would be if the total amount of ozone present in the whole atmosphere were uniformly distributed through the atmosphere.

Methods of measuring the amount of ozone which involve the use of photographic plates suffer from great disadvantages owing to the great labour involved before the amount of ozone can be ascertained and the long time which must necessarily elapse before the results of the measurements can be known. For this reason a new type of photoelectric instrument has been designed and made which allows the amount of ozone to be measured within a total time of five minutes. The new instrument allows measurements to be made on direct sunlight, the light from the clear zenith sky, or the light from a cloudy sky. In the latter case an additional measurement with longer wavelengths is also made from which allowance can be made for the effect of the cloud. Arrangements are now being made for this new instrument to be made in quantity by an instrument manufacturer so that they may be supplied to anyone wanting them.

In 1929 Dr. Götz made a special expedition to Spitzbergen and has obtained very valuable measurements of the ozone content at this high latitude. (See Figures 3 and 4).

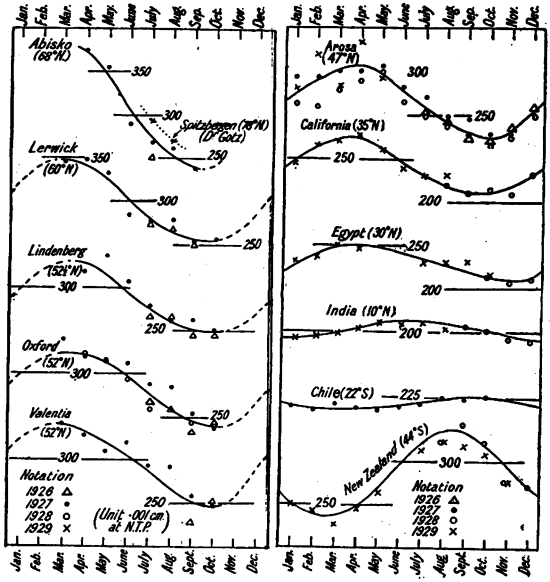

Fig.3.

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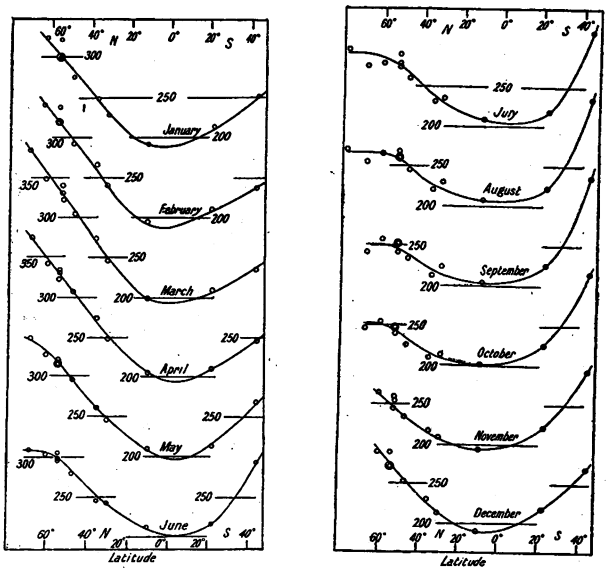

FIG. 4.

The questions of the method of formation of the ozone in the atmosphere and the reason why the amount is so closely connected with the pressure distribution are still unsolved. The simple hypothesis that the ozone is transported from regions where there is normally little or much ozone seems to be definitely ruled out by the fact that in the autumn hemisphere the average distribution is nearly uniform from the Equator to the Pole.

There seems to be a small connection between the amount of terrestrial magnetic disturbance and the amount of ozone, the amount of ozone being large when the magnetic conditions are disturbed.

Future Programme. Owing to the great advantages possessed by the new photoelectric instruments it is hoped that it may be possible to arrange for a considerable number of them to be made and for regular observations to be taken at a number of stations in Europe in order to study further the relation between the amount of ozone and the pressure distribution. It is also very desirable that observations should be taken at many other places scattered over the World for a considerable number of years. Unfortunately the new instruments are necessarily rather expensive and work will be limited by the amount of money that can be obtained for this work.

March, 1931.

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TREE GROWTH AND SOLAR CYCLES

By A.E. Douglass.

1. The use of tree rings in the study of climatic variation began as an astronomical investigation based on the hypothesis that changes in the sun affect our weather and should in turn be found in the trees, especially in semi-arid climates. By 1914 long continued sequences of the solar cycle had been traced in the pines of Arizona. A defect in the sequence near 1700 caused much questioning of this conclusion but later through the researches of Maunder it was learned that during this deficient period in the trees there was actually a pronounced dearth of sunspots (1)

2. In using tree rings as climatic indicators, the exact year of growth of each ring is first firmly established by comparisons between many trees. (I-15,(2)). Thus one discovers the existence of errors in individual trees and determines the march of certain climatic changes prevailing over the whole forest. Pests and fires may be distinguished because their results, if the trees survive, are temporary and usually local.

The interpretation of ring widths in the pine trees of northern Arizona and New Mexico, the semi-arid 'Pueblo' area of the archaeologists, points clearly towards rainfall as the controlling factor. (I-65). In the mountains of California moisture plays a less important part but seems to be still present, while in the forests in the more northern States its effect on the trees is less certain. The interpretation of ring width in different climatic regions needs a large amount of detailed study, including the establishment of meteorological stations within the forests chiefly concerned.

3. Cyclograph analysis is generally used (I-86:II-45). This form was begun in 1913 with an instrument which produced a periodogram in accordance with Schuster's suggestion. It was recognised almost immediately that an intermediate stage of the process, devised and used in 1913 and made automatic in 1914, was a more valuable source of information. This consists in a pattern called the cyclogram which is the counterpart in photometric values of the numerical summation table by which a test is ordinarily made of each cycle length in any long series of values. In a written table we are compelled to add vertically but in the optical process the summation can be done at other than vertical angles, thus testing out different cycle lengths. Such summation actually made produces a portion of a periodogram But instead of making the summation, the pattern itself, produced automatically from the curve, is studied and the straightness of alignment of the blotches representing maxima becomes at once the criterion of the existence of a cycle. Several of these diagrams made from the same original curve placed at different apparent distances are used to give a wide range of analysis. The method gives length and phase readily and an estimate of amplitude, and

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(1) The Prolonged Sunspot Minimum, 1645-1715. Jour. Br. Ast. Assoc. XXXII, January 1922, pages 140-145.
See also Some Topographic and Climatic Characters in the Annual Rings of the Yellow Pines and Sequoias of the Southwest. Proc. Am. Phil. Soc. (Philadelphia) LXI. No.2. 1922, page 120.

(2) References are made to Volume I, (1919) and II (1928), Climatic Cycles and Tree Growth: Carnegie Institution of Washington.

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has therefore great rapidity and flexibility in cycle exploration. It is especially applicable to the separation of mixed cycles. The cycles may be constant or slightly variable, broken, intermittent, or affected by change of phase (3). The method is so rapid that on many different occasions forty-two different curves, averaging 175 units in length, have in three hours been analysed for all cycles between 5.5 and 40 units, by one observer.

4. A study of 305 modern pines has been made in the western United States. Their growth curves were divided into forty-two groups about equally scattered in three zones: namely the Rocky Mountain area, the central or Arizona area, and the Sierra Nevada Mountains of the coast. The mean of each group was analyzed and the results collected together by zones. The cycles appear in a great majority of cases to be simple fractions of two or three times the sunspot cycle. This was held to be of sufficient importance to make a complete and independent analytical check before publishing (II-123 and 124). In a general way the Rocky Mountain zone has a tendency to divide the Brückner cycle into halves and quarters. The coastal zone shows more evidence of fractionizing the double sunspot cycle 22.5 years: at some points superb records were obtained of this entire length while in other places subordinate maxima occurred dividing this interval into halves and quarters and sometimes into thirds. The intermediate Arizona area seemed more often to fractionize the triple sunspot cycle, with a strong cycle averaging 20 to 21 years in length in the last 200 years. (Compare the work of Clayton (3), Abbot (5), and C.E.P.Brooks (6).

5. The longest tree records were found in the giant sequoias of California. About a dozen go back to the vicinity of 200 B.C. At least four carry the record back to 1100 B.C. and one extends to 1300 B.C. Any report at this time is preliminary and subject to future more minute study. The sunspot cycle appears to be recognizable in many parts of this record provided one takes as a basis the double value of about 22.5 years. This subdivides into halves, thirds, quarters and fifths. The solar influence is evident as follows: 1300 to 1100 B.C.: near 300 B.C.: 0 to 200 A.D.: near 400 A.D.: after 600 A.D.: much of the ninth century and since 1300 except for an interval near 1700 (II-130). It was noticed that the fractionizing into fifths seemed to occur at significant intervals. When those were analyzed with the cyclograph two solutions were found, one giving a period of about 282 years suggestive of Turner (7), and the other in the form of a double crested cycle of 266 years (8) with a change of phase between 500 and 700 A.D. and a reduced probable error.

The Sequoia growth since 1850 agrees with the rainfall in California in presenting the Hellmann relation described in the next section.

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(3) Reports of the Conferences on Cycles. Carnegie Institution of Washington, 1929, page 34.
For first publication, see 'A Photographic Periodogram of the Sunspot Numbers.' Astroph.Jour. Vol.XL, No.3: 326, October 1914.
(4) The Atmosphere and the Sun, Publication 3062 Smithsonian Institution, June, 1930, page 33.
(5) Weather dominated by Solar Changes. Publications 3114 Smithsonian Institution, February, 1931, page 18.
(6) Periodicities in Nile Floods. Mem. Roy. Meteor. Soc. Vol.II January, 1928, page 21.
(7) The Long-Period Terms in the Growth of Trees. Mon.Not.Roy. Ast. Society, LXXX Sup. no. Oct. 1920, 793.
(8) Note on the 240 Year Period in Chinese Earthquakes. Mon. Not.Roy.Ast.Soc. LXXX No.6. April 1920, page 617.

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6. The record of Arizona pines, Pinus ponderosa, has been extended back in a continuous series to 700 A.D. by the aid of beams from prehistoric ruins (9). A preliminary examination of this sequence indicates well developed cycles of approximately 38 years and 100 years nearly continuous through the interval. Of shorter cycles, 9.5 and 19 seem to be the most conspicuous, giving a probable basis for the 38-year cycle and suggesting a possible explanation of the frequent maximum at 20 or 21 years (section 4 above and II-124) as a combination of 19, well developed in Arizona, and 22.5 which is prominent in California. Interesting patterns also appear between 10 and 12 years in which a sunspot cycle of a little more than 11 years can be traced through a considerable portion. This latter appears to break into halves, which is the Hellman relation, at a number of places: for example A.D. 1200, an extended period near 1500 and for a shorter interval near 1800. The absence of this cycle near 1700 and its replacement by a cycle between 9 and 10 years in length is easily noted (II-126).

'Hellman relation' is the name tentatively given to the half sunspot cycle having a length of about 5.5 years. It is perhaps an 11 year cycle with two maxima usually unequal. This cycle is described by Hellmann in his study of the North German Drainege Area, published in 1906 (10). It was observed by the writer in 1906 in the California rainfall and in tree growth in Arizona (11). In 1912 it was found in north European trees with one maximum largely suppressed but not always (I-78, fig. 26). About 1915 it was found highly developed in the Arizona trees during the century or more following 1420 (I-102). This is considered to form a basis for reconstructing the sunspot curve during that interval and such an attempt is being made. This relation may easily be detected in recent California tree growth.

7. Acknowledgment is hereby made to the Carnegie Institution for its important support of these researches in climatic variations. Also it is made to the National Geographic Society through whose valued assistance the archaeological material has been secured which has carried South-western climatic records back to 700 A.D. The American Museum of Natural History assisted in early collections. The Museum of Northern Arizona has given great help in field work. Mr. Clarence G. White supplied funds for the construction of the cyclograph. The University of Arizona has made much of this work possible by reducing teaching obligations.

TUCSON, March 5, 1931.

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(9) The Secret of the South-west Solved by Talkative Tree Rings. National Geographic Magazine, December 1929.

(10) Die Niederschläge in den Norddeutschen Stromgebieten, 1906, page 343.

(11) Weathern Cycles in the Growth of Big Trees. Monthly Weather Review, June 1909, page 227.

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SUR LES MÉTHODES POUR L'ÉTUDE DES VARIATIONS DU RAYONNEMENT SOLAIRE

Note de Ch. Fabry.

L'étude des variations du rayonnement solaire se trouve singulièrement compliquée par les variations de l'absorption atmosphérique; les deux problèmes, celui de l'émission par le soleil et celui de l'absorption atmosphérique sont intimement liés; si l'on observe des variations dans le rayonnement reçu, il est en général impossible de dire si la variation est due à une variation dans l'émission ou à un changement dans l'absorption. Il est même évident que, dans la plupart des cas, c'est cette dernière cause de variation qui est la plus importante et la plus probable à priori. Il se trouve que l'étude des variations du soleil est beaucoup plus difficile que celle des étoiles, car les étoiles voisines d'une variable peuvent servir d'étalons, et la comparaison élimine l'effet des variations atmosphériques; pour l'étude du soleil, il est impossible d'employer une méthode analogue. On en est réduit à mesurer le rayonnement reçu et à essayer de calculer l'absorption atmosphérique pour en déduire le rayonnement avant son passage à travers l'atmosphère terrestre.

Un grand nombre d'observatoires font journellement des observations actinométriques, qui donnent la valeur du rayonnement total reçu; il est impossible d'en déduire une indication quelconque sur les variations solaires. Certaines observations, comme celles de E. Pettit au Mount Wilson, sont basées sur la comparaison des rayonnements reçus à travers deux filtres différents; de ces observations on peut déduire que, d'un jour à un autre, quelque chose a changé; mais l'interprétation correcte est impossible.

Une seule méthode existe pour tenir compte correctement de l'absorption atmosphérique, c'est la méthode de BOUGUER-LANGLEY, basée sur l'observation de l'intensité des radiations monochromatique au cours d'une même journée. Elle est régulièrement appliquée par ABBOT et ses collaborateurs à la Smithsonian Institution. Toutes les observations sont faites par la méthode thermique, et le but principal est la détermination de la 'constant solaire', qui mesure le rayonnement total venant du Soleil. Du point de vue théorique, cette méthode est parfaite; elle ne paraît cependant pas, à elle seule, donner une solution entièrement satisfaisante du problème des variations solaires. Tout d'abord, elle est d'un emploi difficile et exige des appareils très délicats; autant que je peux le savoir, elle n'a jamais été employée par d'autres personnes que les habiles observateurs de la Smithsonian Institution; or il serait très important d'avoir des mesures simultanées en un grand nombre de lieux différents, et l'emploi de plusieurs méthodes serait désirable. De plus, la méthode est orientée vers l'étude de la 'constante solaire'; l'enregistrement du spectre intervient seulement comme un intermédiaire nécessaire pour arriver à cette 'constante'; or il se peut très bien que le rayonnement solaire présente des variations dans certaines régions spectrales, qui pourraient ne se traduire que par de très petites variations sur le rayonnement total. C'est dans la région des courtes longueurs d'onde que l'on peut attendre les plus fortes variations, et sur cette région la méthode bolométrique ne donne que des indications insuffisantes. Comme la région des courtes longueurs d'onde n'intervient que pour une très faible part dans la 'constante solaire', de fortes variations dans cette région ne seraient pas décelées par les mesures de la 'constante'.

En résumé, le problème des variations du soleil n'est pas encore résolu. On ne peut se contenter de mesures donnant le rayonnement total; les variations spectrales devraient être etudiées particulièrement dans la région des courtes longueurs d'onde.

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On doit d'abord se demander quelle méthode nouvelle pourrait être employée pour attaquer le problème.

La méthode de mesure par le récepteur thermique (bolomètre, thermopile, etc..) est la seule qui puisse donner une mesure directe de l'énergie reçue, soit de l'énergie totale soit de celle qui correspond à une région spectrale donnée. Mais cette méthode sera toujours d'un emploi très délicat et manquera de sensibilité. Les autres récepteurs (oeil, appareils photo-électriques, plaque photographique) sont d'un emploi beaucoup plus facile, et (excepté dans l'infra-rouge) d'une bien plus grande sensibilité. Malheureusement, ces appareils font seulement des comparaisons entre rayonnements de même longueur d'onde. On est alors inévitablement conduit à la conclusion suivante:

Il est indispensable de faire des mesures sur les diverses radiations simples, par comparaison avec une source artificielle servant d'étalon.

Les astronomes paraissent, en général, peu favorables à l'emploi d'étalons terrestres dans les observations astronomiques. Il est évident que leur emploi est une cause supplémentaire d'incertitude, à cause des variations possibles de l'étalon. Dans le cas actuel, l'étalon artificiel me paraît cependant une nécessité, et devra conduire à d'excellents résultats à la condition de le choisir et de l'employer avec toutes les précautions en usage dans les laboratoires de photométrie. Il n'est d'ailleurs pas théoriquement nécessaire que les étalons employés dans divers observatoires soient comparables entre eux; il suffit que, pour chaque série de mesures, on ait un étalon constant. Il paraît possible d'avoir une constance garantie à quelques millièmes près. Je rappellerai que des étalons artificiels ont déjà été employés en spectrophotométrie astronomique, en particulier par M. Jules Baillaud.

La lampe électrique à incandescence fonctionnant sous un régime défini paraît être, dans l'état actuel de la technique photométrique, l'étalon le plus commode et le plus sûr. Naturellement, le régime électrique doit être contrôlé avec une grande précision; l'emploi d'un potentiomètre est à recommander. Si l'on veut pousser les mesures aussi loin que possible vers les petites longueurs d'onde, il sera nécessaire d'employer une lampe avec ampoule ou fenêtre en silice fondue. La lampe à hydrogène de M.M. Chalonge et Lambrey, qui donne un spectre continu intense dans l'ultra-violet, doit aussi être prise en considération.

Une fois admis le principe de la 'lampe étalon' la mesure se réduit à une comparaison spectrophotométrique. Cette comparaison se faisait toujours par 'égalisation', le résultat sera indépendant de l'appareil récepteur utilisé; ce sont des questions d'opportunité qui feront choisir tel ou tel récepteur. Aucun ne doit être rejeté à priori. Il faut considérer les suivants: l'oeil (dont l'emploi, dans la région moyenne du spectre visible, est commode et précis), la photographie, les cellules et piles photoélectriques, les corps analogues au sélénium. On arrivera à faire des mesures relativement faciles dans toute l'étendue du spectre depuis l'extrémité de l'ultra-violet jusque vers 1μ. Pour l'infra-rouge au-delà de 1μ, on serait obligé de recourir à la thermopile ou aux instruments analogues; mais cette région, très importante pour la mesure du rayonnement total, est probablement la moins intéressante pour déceler les variations du Soleil.

On doit se demander quelle région spectrale il convient de surveiller plus particulièrement. C'est dans l'ultra-violet que l'on a le plus de chances de trouver des variations; mais les autres régions devraient être étudiées aussi. Dans le choix des régions étudiées il faudra tenir compte des considérations suivantes:

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Il faudra éliminer les régions où l'absorption atmosphérique introduit de trop grandes difficultés dans l'interprétation des résultats. La loi classique de l'absorption en fonction de l'épaisseur s'applique toujours à une radiation rigoureusement monochromatique; mais si la dispersion n'est pas très grande, la loi n'est pas applicable dans les régions où existent des raies telluriques fines non séparées. D'une manière plus générale, la loi ne s'applique qui si, dans la petite région sur laquelle porte le mesure, l'absorption est constante. Ceci conduit à éliminer, par exemple, le région du rouge et de l'orangé qui contient les bandes d'absorption compliquées dues à l'oxygène et à la vapeur d'eau.

L'absorption par l'ozone introduit de sérieuses complications dans l'extrême ultra-violet. Elle est fortement selective:, la mesure de l'absorption atmosphérique n'a de sense que pour une radiation bien définie. De plùs, cette absorption est variable d'un jour à un autre. Enfin la loi simple qui donne l'intensité transmise en fonction de la distance zénithale ne s'applique pas aux grandes distances zénithales à cause de la présence de l'ozone dans la très haute atmosphère. Malheureusement, ces difficultés se trouvent dans la région des très courtes longueurs d'onde, qui est la plus intéressante pour le problème que nous avons en vue.

Bien que cette note n'ait pas pour but de proposer un type déterminé d'appareil, je désire présenter à ce sujet quelques considérations générales.

CHOIX DE L'APPAREIL DISPERSIF - Une très grande dispersion ne paraît pas nécessaire. D'autre part, il faut éviter toute lumière diffusée. Je pense que les prismes devront être préférés au réseau: naturellement, pour l'étude de l'ultra-violet il faudra employer des appareils en quartz.

Pour l'élimination complète de la lumière diffuse, le moyen le plus parfait est l'emploi d'un spectrographe double. Son emploi est nécessaire pour l'étude de la région tout à fait extrême de l'ultra-violet, par exemple au-dessous de 3,000. Si on renonce à étudier cette région difficile on pourra probablement éviter la complication du spectrographe double. Il faudra prendre les précautions nécessaires pour réduire au minimum la lumière diffusée, comme dans les expériences de M. Lyot sur la couronne solaire (poli parfait des surfaces, choix de matières sans défauts d'homogénéité, élimination des poussières).

CHOIX DE L'ÉTENDUE SPECTRALE POUR CHAQUE MESURE. - Le pouvoir séparateur de l'appareil dispersif, ainsi que celui de l'appareil récepteur, n'est pas infini; la mesure porte toujours sur une largeur finie du spectre, et la comparaison avec l'étalon photométrique se fera sur la même étendue. Quelle largeur convient-il de choisir?

Il faut d'abord la prendre assez faible pour que le coefficient d'absorption atmosphérique ait une valeur bien définie; dans certaines régions du spectre, la limite ainsi imposée est très large. Dans les essais entrepris autrefois par M. Chrétien (interrompus par la guerre et non encore repris) on fait chaque mesure sur une assez grande largeur du spectre (quelques dizaines d'angströms par exemple) en recombinant les radiations d'une petite bande spectrale pour les mesurer ensemble. Cette méthode paraît très bonne, excepté dans l'extrême ultra-violet où l'absorption varie très rapidement avec la longueur d'onde.

Si l'on fait directement la mesure dans le spectre, il faut faire attention à une difficulté tenant à la présence de nombreuses raies d'absorption solaire. Le rapport des intensités du soleil et de la source pourra varier avec la largeur de la fente.

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CHOIX DE L'APPAREIL RECEPTEUR. - Les mesures étant faites par égalisation, tout appareil récepteur peut donner des comparaisons correctes avec l'étalon. Le choix de l'appareil récepteur est une question de commodité.

Dans l'ultra-violet, on peut employer la plaque photographique et la cellule photo-électrique. La photographie a l'avantage de donner en une seule pose ce qui est nécessaire à un grand nombre de mesures; mais le dépouillement des clichés est long et délicat. La cellule photo-électrique est probablement plus précise, mais moins sensible, et exige une installation plus compliquée.

Dans le visible, on pourrait aussi faire des mesures visuelles, qui peuvent donner de bonnes mesures à peu de frais.

Enfin, la thermopile pourrait être employée dans le visible et l'infra-rouge.

EMPLOI D'UN DIFFUSEUR. - Il faut examiner très soigneusement la manière dont les flux lumineux pénètrent dans l'appareil dispersif et sont finalement utilisés par l'appareil récepteur. La méthode la plus simple pour éviter toute difficulté paraît être de placer devant la fente de l'appareil dispersif, un diffuseur qui serait éclairé directement par le soleil (avec des diaphragmes arrêtant la lumière diffuse du ciel), et serait ensuit éclairé par la lampe étalon pour faire la comparaison. Les propriétés de ce diffuseur se trouveraient éliminées. Toutefois, il n'est pas facile d'obtenir un bon diffuseur par transmission pour l'ultra-violet.

La mesure faite en lumière diffusée se rapportera au rayonnement par l'ensemble du disque solaire; c'est la seule quantité intéressante pour l'étude de l'influence solaire sur les phénomènes terrestres. Le problème des différences entre les points de la surface solaire (centre et bord) taches, facules, etc..) n'est intéressant que pour la Physique solaire et doit être traité à part.

MESURES VISUELLES À TRAVERS UN FILTRE. - Les mesures visuelles, par comparaison avec un étalon, seraient très faciles s'il était possible de les faire à travers un filtre suffisamment monochromatique pour que le coefficient d'absorption atmosphérique ait un sens. Dans la région verte, où il y a peu d'absorption sélective et où l'oeil est très sensible, il ne serait peut-être pas impossible de trouver un tel filtre. On arriverait ainsi à une méthode de mesure très simple, qui pourrait être employée en un grand nombre de stations. Toutefois, ces mesures n'apprendraient rien sur les variations de l'ultra-violet solaire.

CHOIX DES LIEUX D'OBSERVATION. - Ce choix serait fondamental. La méthode de Bouguer- Langley, la seule dont nous disposions pour mesurer l'absorption atmosphérique, suppose une atmosphère identique à elle-même au cours de chaque journée d'observation. Le voisinage immédiat des villes est évidemment à éviter.

Chaque mesure donnera, pour une région donnée du spectre, le rapport entre l'éclairement produit par le soleil à travers l'atmosphère et l'éclairement produit par la lampe étalon à une distance déterminée. En combinant ensemble les observations d'une même journée, on en déduira la valeur du même rapport pris avant l'absorption atmosphérique, ainsi que la valeur du coefficient d'absorption de l'atmosphère. Les variations de ces deux éléments pourront être étudiées.

D'autre part, on peut étudier la courbe spectrale d'énergie de la lampe étalon (par example par comparaison avec un corps noir); on pourra alors tracer la courbe spectrale d'énergie du soleil, qui est très mal connue du côté des petites longueurs d'onde. Cette courbe peut être tracée de deux manières: on peut faire les mesures sur de très petites portions du spectre solaire choisies en dehors des raies d'absorption, ce qui donne la courbe d'intensité du fond continu; on peut aussi prendre des bandes plus larges et obtenir la courbe des intensités moyennes réelles. Cette dernière est seule utile pour l'étude des effets du rayonnement solaire; la première est interéssante pour la théorie du soleil.

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MAGNETIC SECULAR-VARIATION AND SOLAR ACTIVITY.

By Harlan W. Fisk.

An examination of the year-to-year differences of the annual mean-values of the magnetic horizontal-intensity for any well-conducted observatory will show great irregularity. It has been shown in discussions by Moos (1; see references at end of paper), Schmidt (2), Bauer (3,, Chree (4), and others that a part at least of this irregularity is accounted for by varying magnetic activity which increases with solar activity as indicated by the sunspottedness. There have now become available consecutive annual mean-values from 25 observatories for all the years 1903 to 1927, inclusive, with a few minor exceptions, permitting a comparison of the character of this variability in widely separated regions.

It is well known that after a magnetic disturbance the intensity remains subnormal for several days, so that as storminess increases toward the year of sunspot-maximum the number of subnormal days becomes greater, resulting in a diminished annual mean-value. As a consequence the apparent secular-rate at any station tends to a minimum when the storminess is increasing most rapidly. There is a diversity of practice among observatories in reporting the monthly means, some including the daily means for all days indiscriminately and others using the means only of selected quiet days. Unless the subnormal values persist from one period of disturbance to the following, it would be possible to eliminate much of the apparent variation in the secular rate which arises from these after-effects of magnetic storms by deriving the annual means from quiet days selected so as to avoid those immediately following great disturbances during which the depression is greatest. How far this is effective may be estimated from an examination of the results from the five observatories of the United States Coast and Geodetic Survey, for which the monthly means are given from all days (A) and from ten selected quiet days (Q), care having been used in selecting the days to avoid as far as possible those in which the after effects of the storms are most apparent. When the difference (Q - A) is found by subtracting the annual means for all days from the mean for the quiet days, this difference is found to be uniformly positive even in years of very small activity (except for Baldwin in 1901), but increases systematically from sunspot-minimum to sunspot-maximum, as shown in Figure 1. Obviously the magnitude of the difference (Q - A) will

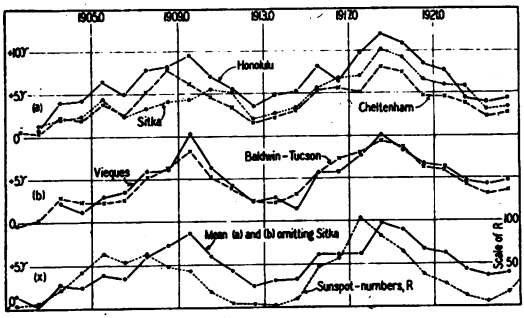

Fig. 1. - Difference (Q - A) between annual mean-values of magnetic horizontal-intensity from ten selected quiet days for each month and from all days, 1901-24, for observatories of the United States Coast and Geodetic Survey.

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vary slightly with the selection of the quiet days, and will be influenced by the success achieved at the observatory in securing records for every day, particularly those of great disturbance. It will be noted that the maximum which appears in four of the curves in 1908-09 is wanting in the Sitka curve doubtless because records of many days were lost during those years at that observatory.

That any selection of ten quiet days which will fairly represent the undisturbed mean for the month is inadequate to eliminate apparent fluctuation of secular rate with activity, is shown by Figure 2 in which are plotted the year-to-year differences

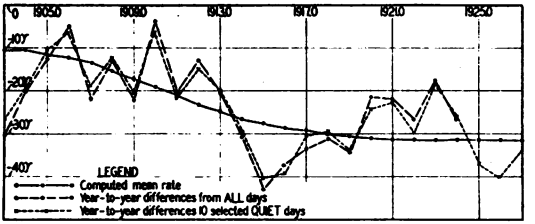

Fig. 2. - Rate of annual secular-change in magnetic horizontal-intensity at Honolulu, 1903-21, derived from all days and from ten selected quiet days for each month.

of annual mean-values derived both from all days and from ten selected quiet days each month as published in the reports of the Honolulu Observatory, selected because for the five observatories of the Coast and Geodetic Survey its (Q - A) - curve had the greatest amplitude. From this graph it is seen that the activity-effect on the apparent secular-rate has been reduced somewhat by the use of selected-day means (from which the published annual mean-values are obtained) instead of the all-day means used by some observatories. That the difference in the amplitudes of the fluctuations of the rate-curves whether from all or selected days is relatively small, shows that the subnormal values of the horizontal component persist continuously throughout the period of great solar and geomagnetic activity (see also column 7 of Table 2).

The purpose of the investigation of which the following paragraphs is a condensed report was to determine: (a) Whether there are fluctuations in the apparent secular-rate which conform closely to the sunspot-cycle; (b) to what extend the fluctuations are regional or world-wide; and (c) whether it may be possible to detect world-wide effects which do not conform to the sunspot-cycle.

In order that the results should be strictly comparable, the data from all observatories were treated the same way. Only those were utilized for which annual values in an unbroken series from 1903 to 1927, inclusive, were available exception being made where a good transfer from an old location to a new one was possible, and in a few cases where an end-value was extrapolated to secure a series of the desired length. In the present state of our knowledge it is not possible to say what part of the apparent secular-change is true secular-change (that is, a change in either the direction or intensity of the permanent magnetization or both), what part arises from regional causes within the Earth, and what part comes from without probably inducing coincident changes within. As a working hypothesis it is assumed that the true secular-variation and the regional changes (5) are of longer period than those of

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solar or cosmical origin and so may be eliminated by adjusting the observed annual mean-values to a smooth curve computed according to a suitable formula. For this purpose the second-degree or parabolic formula has generally been used for periods not longer than the 25 years covered by this investigation, but since this assumes a uniform or uniformly changing rate it is quite obviously unsuited to many localities. A more flexible formula and one which lends itself to rapid computation, especially where a large number of similar operations are to be performed, was adopted as follows:

$$H = H_0 + r\ (T - T_0) + \alpha_1 \sin\theta + \alpha_2 \sin 2\theta + \alpha_3 \sin 3\theta$$

in which r is an assumed uniform rate from the initial to the final year of the series, the initial year $T_0 = 1903.5$, and $\theta = (\pi/24)(T - T_0)$. The periods represented by the last three terms, 48, 24 and 16 years, respectively, are too long to disturb seriously the evidence of an 11-year period or any shorter periods which may exist, although certain regional changes may still remain to confuse the results.

A comparative representation of the changes at different observatories is conveniently made by means of graphs showing annual rates rather than absolute values of the element. These rates may be derived from the year-to-year differences between computed annual values, and differences similarly taken from the observed values from which some of the abrupt changes have been smoothed by averaging each annual value with the mean of the preceding and following. The departure (Δ_r) of the observed from the computed annual rate is shown for a few typical cases in Figure 3. The similarity of the first three graphs a, b, and c, for such widely separated observatories as Honolulu and Valencia or De Bilt indicates clearly a world-wide cause of the fluctuations from the mean, particularly when the difference in magnetic latitude as well as geographic position is considered. The (Δ_r)-curve in the next five graphs (d-h) of Figure 3 for European observatories from Coimbra on the west to Sverdlovsk (Katharinenburg) on the east, are similar in phase to each other and to those above but differ progressively in amplitude. What relation this progressive difference may bear to magnetic or geographic latitude is not immediately apparent, and its determination is complicated by the difficulty of eliminating the regional characteristics. For example, the amplitudes of the departures at Cheltenham and Agincourt (i and j, Fig. 3) are much greater than those of Sverdlovsk and Pavlovsk whose magnetic latitudes are comparable, but all these observatories are relatively near centers where large regional changes are known to be taking place (6), and it is very probable that the departures shown in the graphs are affected by them.

The similarity in the departure-curves for all the observatories indicates a world-wide effect and therefore a common cause, but attention is called to some features common to practically all regions which do not conform to solar activity as indicated by sunspots. These detailed features may be better studied in Figure 4 which shows the fluctuations of the absolute annual mean-value of horizontal intensity, H, about the computed mean (designated Δ_a, instead of the variations of annual-rate, Δ_r, shown in the previous figures). To economize space, curves which were very similar in phase and amplitude have been combined and the mean plotted. In this way some features in individual cases have been lost and a slight smoothing effected, but the significant characteristics have been preserved. In the first group (a) of the Δ_a- graphs of Figure 4 comprising stations of highest geographic latitude (Sitka, Christchurch, Pavlovsk, Sverdlovsk), the mean amplitude is smaller than for other stations though there is little difference in phase. In the second group (b) the curves for the three stations (Bombay, Irkutsk, and Coimbra) were plotted separately because of an unusual irregularity which they possess in common between 1920 and 1923

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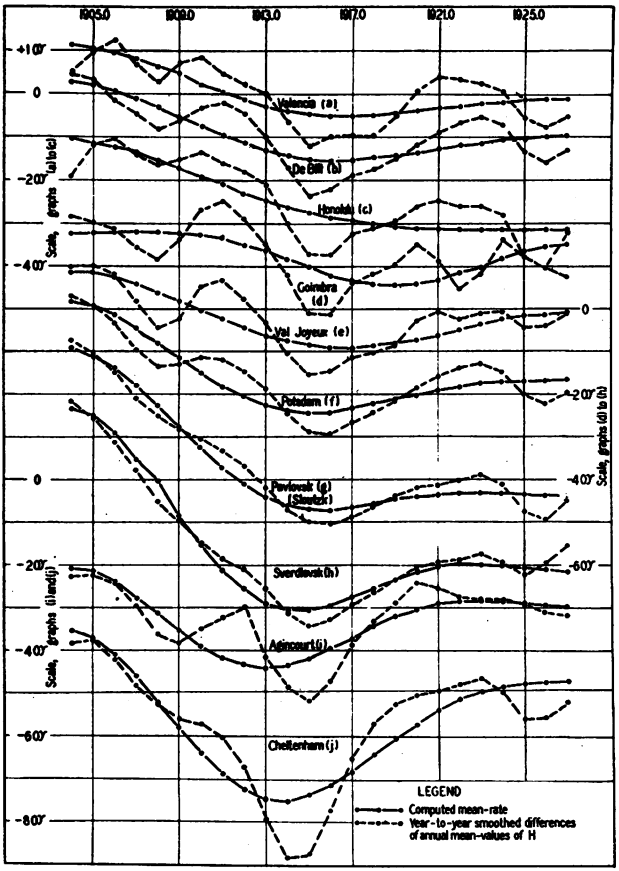

Fig. 3. Comparison of observed and computed yearly rates of change in magnetic horizontal-intensity, 1903-27, at ten observatories.

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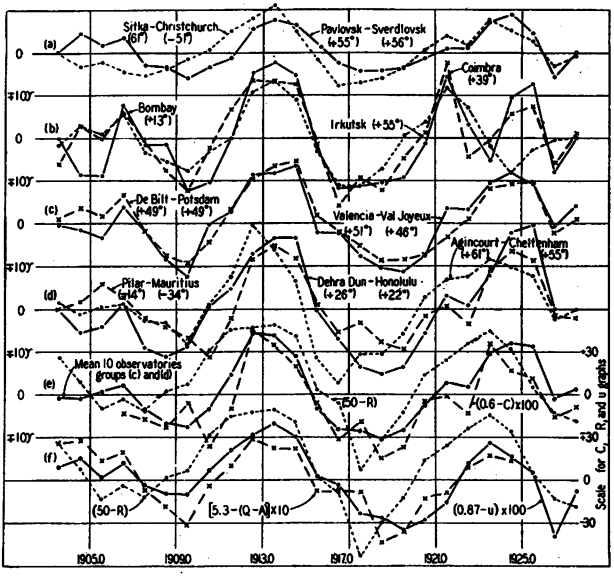

Fig. 4 - Graphs comparing differences between observed and computed annual mean-values of magnetic horizontal-intensity, of magnetic character-number (C), of interdiurnal variability (u) after Bartels, of difference (Q - A) between quiet-day means and all-day means, and of Wolfer sunspot-numbers (R) for 1903-27 - the magnetic latitudes for each station are given in parentheses.

notwithstanding the difference in magnetic and geographic co-ordinates of the observatories. The practical coincidence of the two curves in (c) - De Bilt-Potsdam and Valencia-Val Joyeux - is not surprising considering the positions of the observatories; it is of interest to note that the secondary maximum of 1921, greatly exaggerated in (b) and appearing in definite but diminished magnitude in most of the other observatories, is entirely missing from the Potsdam and De Bilt graphs. In group (d) Honolulu and Dehra Dun in north magnetic latitude, and in the same group the mean of Cheltenham and Agincourt of much greater magnetic latitude is drawn to show the similarity of amplitude. However, as was indicated in the preceding paragraph, it is probable that regional peculiarities affect the curve for the latter stations, further evidence of which is seen in the definite indication of a shift of phase.

While some of the irregularities in these Δ_a-curves may have been caused by instrumental changes or by methods of reduction, it is scarcely possible that a feature such as the secondary maximum in 1906 where a minimum would be expected, or that in 1921 already noted, or the delayed maximum of 1924-25, would appear universally except from some real cause. It seems quite possible that what has been discussed as 'lag' of magnetic behind solar activity may be the result of the superposition upon the period of sunspot-activity of sporadic causes or of some form of activity having a shorter period.

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In groups (e) and (f) of Figure 4 a comparison of relative sunspot-numbers is made with magnetic activity indicated in four different ways: (a) by the mean departure, Δ_a, for the ten observatories of groups (c) and (d) of the observed annual mean-values of horizontal intensity from the computed mean; (b) by annual mean of the international magnetic character-numbers (7); (c) by the difference ($\underline{Q}$ - $\underline{A}$) of the annual means derived from quiet days and from all days; and (d) by the universal u-measure (8) of activity derived from several observatories up to 1920 and later from Potsdam only (9). In these groups all except the Δ_a-curve are inverted and adjusted to a scale comparable with those of the other groups of the same figure.

In Table 1 the data are given concerning 25 stations for which the successive annual values (with minor exceptions) for the 25 years 1903 to 1927 are available and for which the departure-curves, Δ_r and Δ_a, were computed. Seventeen of these showed very close similarity in all graphs as illustrated in Figures 3 and 4, while the eight marked with asterisks either disclosed disagreements which need further investigation or because of interruptions were considered unreliable and were not used. The geomagnetic coordinates are taken from a table by Bartels in the Handbuch der Experimental Physik (10) and are defined as follows: The geomagnetic latitude, Φ, is the complement of the great-circle distance from the north pole of the magnetic axis in north latitude 78°5 and east longitude 291°; the geomagnetic longitude, Λ, is measured eastward from the geographic meridian passing through this magnetic pole. The magnetic latitude, φ', is as determined from the formula tan φ' = (1/2) tan I, the magnetic inclination, I, and horizontal intensity, H, being taken for the mean year 1915. Since

Table 1. Geographic and geomagnetic coordinates and measures of irregularities of magnetic secular-variation for 25 observatories, 1903-27.

Observatory.	Geographic		Geomagnetic		Mag'c lati-tude	Hor. int.	Summation departures 1903-27.	
	Lati-tude φ	Long. east λ	Lati-tude Φ	Long. east Λ	φ'	H	$\Sigma\Delta_a$	$\Sigma\Delta_a/H$
	°	°	°	°	°	cgs	γ	
Pavlovsk	+59.7	30.5	+56.0	117.0	+55.3	.162	99	.0061
Sitka	+57.0	224.7	+60.0	275.4	+60.8	.156	126	.0081
Sverdlovsk	+56.8	60.6	+48.6	140.4	+55.9	.171	82	.0048
Stonyhurst*	+53.8	357.5	+57.0	82.7	+52.1	.173	(254)	(.0148)
Irkutsk (old)	+52.3	104.3	+40.8	174.6	+55.1	.196	133	.0068
Potsdam	+52.4	13.1	+52.5	97.1	+48.9	.187	138	.0074
De Bilt	+52.1	5.2	+53.8	89.4	+49.4	.185	161	.0087
Valencia	+51.9	349.8	+56.6	73.5	+51.2	.179	182	.0102
Kew*	+51.5	359.7	+54.2	83.5	+49.6	.185	(130)	(.0070)
Val Joyeux	+48.8	2.0	+51.3	84.5	+46.5	.197	152	.0077
Agincourt	+43.8	280.7	+55.0	347.0	+61.3	.160	150	.0094
Coimbra	+40.2	351.6	+45.0	70.2	+39.4	.231	172	.0074
Cheltenham	+38.7	283.2	+50.1	350.5	+55.1	.194	219	.0113
San Fernando*	+36.5	353.8	+41.0	71.3	+34.8	.250	(259)	(.0104)
Lukiapang*	+31.3	121.0	+20.0	189.1	+27.0	.332	(157)	(.0047)
Dehra Dun	+30.3	78.0	+20.5	149.9	+26.2	.331	226	.0068
Hongkong*	+22.3	114.2	+10.8	183.0	+16.6	.372	(430)	(.0116)
Honolulu	+21.3	201.9	+21.0	266.5	+22.4	.290	190	.0066
Alibag	+18.6	72.9	+ 9.5	143.6	+12.8	.369	199	.0054
Vieques*	+18.2	294.6	+29.6	3.9	+31.5	.283	(166)	(.0059)
Batavia*	- 6.2	106.8	-17.6	175.7	-17.1	.367	(306)	(.0083)
Apia*	-13.8	188.2	-16.0	260.2	-16.0	.354	(100)	(.0029)
Mauritius	-20.1	57.6	-26.6	122.4	-33.6	.232	158	.0068
Pilar	-31.7	296.1	-20.2	4.6	-13.5	.255	168	.0066
Christchurch	-43.5	172.6	-48.0	252.6	-51.1	.224	84	.0038

* Observatories not used in the present discussion.

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the amplitudes of the departure-curves are governed to an appreciable degree by the arbitrary choice of the formula from which the computed curves are derived only a rough measure of their magnitude is warranted. Such a measure is supplied by the column giving the sum of the departures taken without regard to sign; those enclosed in parentheses were not used. It is quite apparent that the departures from the mean curves are not dependent upon geographic position simply, nor are the inequalities much improved when they are regarded as proportional parts of horizontal intensity as shown in the last column of Table 1.

Table 2. Solar and Terrestrial-magnetic data, 1901-27.

Year	Wolfer sunspot-number R	Magnetic character-number C	Inter-diurnal variability. u	Mean Δ_a for 10 observatories.	Mean (Q-A) for 4 observatories.	$(r_Q - r_A)$ for Honolulu.	Mean r for 20 observatories.
				γ	γ	γ	γ
1901	2.7	....	0.49	....	+0.2	...	...
1902	5.0	....	0.50	....	+0.4	...	...
1903	24.4	....	0.78	- 0.9	+3.0	+3.2	...
1904	42.0	....	0.72	- 1.0	+2.5	+0.3	0.0
1905	63.5	....	0.85	+ 0.7	+4.0	+2.2	+0.7
1906	53.8	0.646	0.76	+ 2.0	+3.4	-1.5	0.0
1907	62.0	0.658	0.92	- 4.0	+6.1	+2.8	-2.5
1908	48.5	0.678	0.97	- 6.6	+7.2	+0.5	-4.1
1909	43.9	0.620	0.98	- 7.5	+8.6	+1.3	-0.8
1910	18.6	0.723	0.81	- 3.5	+5.8	-2.5	+3.2
1911	5.7	0.634	0.67	+ 4.5	+4.3	-1.6	+6.0
1912	3.6	0.455	0.56	+14.1	+2.5	-2.0	+6.1
1913	1.4	0.485	0.48	+13.8	+3.1	+0.5	+2.9
1914	9.6	0.535	0.59	+ 8.9	+3.0	+0.3	-2.8
1915	47.4	0.620	0.85	- 3.7	+6.2	+3.9	-8.1
1916	57.1	0.708	0.92	- 8.2	+6.2	-1.7	-6.3
1917	103.9	0.666	1.12	- 8.7	+7.5	+3.2	-1.6
1918	80.6	0.751	1.15	-10.5	+9.8	+2.3	+0.3
1919	63.6	0.726	1.23	- 8.5	+8.8	-1.0	+2.0
1920	37.6	0.620	1.16	- 2.8	+6.6	-2.5	+5.0
1921	26.1	0.608	1.03	+2.7	+6.2	-0.8	+3.4
1922	14.2	0.646	0.76	+1.9	+4.3	-3.2	+1.2
1923	5.8	0.483	0.62	+9.3	+3.6	-0.5	+1.5
1924	16.7	0.545	0.71	+12.0	+3.9	+0.4	+1.5
1925	44.3	0.562	0.82	+11.3	...	...	-2.8
1926	63.9	0.652	1.26	- 1.0	...	...	-4.3
1927	69.0	0.630	0.96	+ 1.1	...	...	...

Table 2 includes for 1901-27 the annual mean observed Wolfer relative sunspot-numbers (R) and two measures of magnetic activity, namely, the annual mean magnetic character-number (C) compiled by the International Commission of Terrestrial Magnetism and Electricity and the annual mean interdiurnal variability (u) after Bartels. The mean departures in horizontal intensity of the observed from the computed annual mean values (Δ_a) given in Table 2 are averages for the ten observatories Agincourt, Cheltenham, Valencia, Potsdam, de Bilt, Val Joyeux, Dehra Dun, Honolulu, Pilar, and Mauritius (see groups (c) and (d) of Fig. 4). The mean annual values of (Q-A) - the difference between the values of horizontal intensity from 120 selected quiet days (ten in each month, and from all days - are the averages for the four series at Cheltenham, Vieques, Baldwin-Tucson, and Honolulu. The values in the seventh

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column of Table 2 show the differences ($r_Q - r_A$) between the annual rates of change in horizontal intensity from means for selected quiet days and for all days at Honolulu. The mean departures (Δ_r) of the annual rates of change in horizontal intensity given in the last column of Table 2 are compiled from the published annual values for the observatories listed in Table 1 except Lukiapang, Hongkong, Batavia, Apia, and Stonyhurst - a total of twenty. It is to be noted that the values ($r_Q - r_A$) and Δ_r apply to the year centering at beginning of the year against which they are entered while other values of Table 2 apply to the mean of the year. To avoid confusion in plotting the graphs of Figure 4 and to make the graphs readily comparable, the quantities R, C, and u have been subtracted from a quantity displaced from the mean as indicated in the Figure.

From the foregoing it is apparent that a large portion of the irregularities in the apparent secular-rate of horizontal intensity are connected with the after-effects of magnetic disturbances; that the effects are world-wide though the magnitude of the departures indicated are connected in some way with geographical position and also when expressed in absolute units with the magnitude of the component at the place; that the regional characteristics may be of such a character that their effects are compounded with those of the after-effects of storms; and that occasional outbursts, not in step with the 11-year cycle, may introduce irregularities out of phase with the general period. There is the possibility also indicated that there are other periods than the 11-year period which by combination produce a resultant curve which may appear as a lag in the principal period.

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RESEARCHES OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM OF THE CARNEGIE INSTITUTION OF WASHINGTON BEARING ON SOLAR ACTIVITY AND THE EARTH'S MAGNETIC AND ELECTRIC FIELDS.

by J. A. Fleming.

Since the communications submitted on the research work of the Department of Terrestrial Magnetism for the first report of the Committee, investigations of solar activity and the Earth's magnetic and electric fields are summarized briefly below.

W. J. Peters (1) has in progress the application of stereographic projection to the analysis and investigation of magnetic disturbances and their relations to solar conditions. Study was made by him and by W. F. Wallis of the directions in space and of geographic distribution of the initial changes in the Earth's magnetic field as indicated by the magnetograms recorded at twenty-five observatories at the beginning of the magnetic storm of September 21, 1925. So far as the work has gone, the conclusion is drawn that if the interpretations of the traces are strictly according to definition and the origin of the disturbance is cosmical, the local conditions alter its final effects at the respective observatories.

This investigation was supplemented by W. F. Wallis (2,3) in the examination of the geographical distribution of magnetic disturbances through (a) discussion and comparison of photographic records obtained during the MacMillan Baffin Island Expedition at the Bowdoin Harbor Observatory in 1921-22 with those at seven other well-distributed observatories for the storm of March 14, 1922, and (b) by a similar comparison for the storm of January 29, 1924, as recorded at the Refuge Harbor Observatory maintained in 1923-24 by the MacMillan North Greenland Expedition, with magnetograms at nine other well-distributed observatories. The discussions indicate that during these magnetic storms the zone of maximum auroral frequency is the region of most intense magnetic activity and confirm a sharp drop in both auroral frequency and magnetic activity after passing this zone southward with a comparatively low level of magnetic activity in temperate and tropical latitudes except for a slight rise in the region of the magnetic equator. The disturbance-vectors over several months show a marked regularity in direction for individual stations, and for all stations the general direction of the horizontal-intensity disturbance-vector is southward, thus indicating that the disturbed currents in the upper atmosphere flow in general from east to west around the Earth. The results also indicate that local influences not yet understood play a large part in determining the character of the disturbance at any particular spot on the Earth's surface.

An important development which will greatly reduce the laborious compilations so necessary in the study of solar and terrestrial correlations, at least as regards comparison of magnetograms during disturbances indicating solar relations, is that of a photographic method of changing the ratio of ordinate-scale to abscissa-scale by W. J. Peters and J. W. Green (4). This method makes it possible, from magnetograms or other continuous photographic records made at different observatories, to readily reproduce copies to the same scales as regards both time and value of the recorded element with all the minutiae of detail.

In an attempt to obtain a more effective measure of magnetic activity an ordinate-integrator, suggested by C. R. Duvall (5) and designed by C. Huff (6), has been constructed in the instrument shop of the Department. The preliminary tests of this integrator in connection with comparisons of magnetic activity measured by this and other methods not only show excellent correlation-factors for the daily means at the Huancayo and Watheroo observatories but also an unexpectedly close correlation when measuring hourly

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activities. An advantage of this method would appear to be the reproducibility of the definite measure for any particular magnetogram without the inevitable variation due to personal judgment. It is noteworthy that the values obtained are in good agreement with other more laborious mathematical measures of activity as well as with the more simple international character-numbers.

The long series for the u-measure of monthly means of magnetic activity based on the interdiurnal variability of the horizontal intensity is being revised and extended to 1929 by Bartels at the Department of Terrestrial Magnetism. Besides the stations formerly used (Bombay, Batavia, Honolulu, Porto Rico, Potsdam, and Sitka) the series will include Watheroo to represent conditions in the southern hemisphere since 1919. For periods of a month or more the u-measure has been shown to be an adequate measure of activity, especially for comparison with the average sunspot-numbers.

The studies of S. Chapman and J.M. Stagg on the variability of the quiet-day diurnal-variation and its possible bearing on solar ultraviolet radiation are being extended in the harmonic analysis of about 350 very quiet days recorded since 1919 at the Watheroo Observatory.

From investigations of secular-variation data accumulated by the Department, particularly in the Pacific hemisphere, H. W. Fisk (7,8,9) finds from the lines of equal annual change a significant contrast between the acceleration-curves for stations near the center of rapid change and similar curves for stations at a distance. These curves for stations remote from centers of rapid change and widely separated from each other bear a close resemblance to sunspot-curves for the same year, that is to say, the accelerations are positive when the number of sunspots is greater than the mean number. The densely crowded, closed ovals of isopors - lines of equal annual rate of change - around the centers of areas of rapid change undergo movements of dilation and contraction as well as movements of translation; in the case of the horizontal-intensity isopors there is an alternation of expansion and contraction corresponding in period to the sunspot-cycle. This discussion emphasizes the great need in all parts of the world of a more intensive program for the determination of secular-variation changes, particularly at shorter intervals than has heretofore been thought necessary (10).

H. W. Fisk (11), examining the question of an immediate connection between the existence of sunspots and magnetic disturbance has had the advantage of a longer series than that used by Bauer who in 1918 was led to the conclusion from the data then at hand that the lag between solar activity and magnetic activity was greater at times of sunspot-maximum than at times of minimum. Fisk's plotted results form curves which are strikingly similar, the magnetic character-number showing a lag in phase by an amount corresponding to about one-half to three-fourths year. While the investigation does not definitely prove such a lag, the evidence is such as to be strongly suggestive.

In the study of the characteristics of earth-currents at the Huancayo Magnetic Observatory for 1927 to 1929 by O. H. Gish and W. J. Rooney (12), the mean diurnal-variation curves for the individual years are all in very close agreement and the seasonal variation in diurnal range is alike for both components and very similar to that observed at Watheroo (13), the ranges being least in June and in January or February and greatest at the time of the equinoxes.

An investigation of the atmospheric potential-gradient electrograms obtained at Washington, D.C., during 1924 to 1928 by O. H. Gish and K. L. Sherman (14) shows the universal 24-hour term with maximum at $19^h.1$ G.M.T. The phase-angle of this term varied in an approximately periodic manner throughout the year having a

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maximum in April and a minimum in August, this being in rough agreement with the results obtained on the Carnegie as well as with the theory of Wait and Sverdrup (15). A comparison of the secular variation in Wolfer sunspot-numbers and that in the recorded potentials shows a general correlation but with large departures; while the sunspot-minimum occurred in 1923, that in the potential occurred in 1924 or 1925.

W. C. Parkinson and O. W. Torreson (16) investigated the diurnal variation of the electric potential of the atmosphere over the oceans depending upon 82 selected 'normal' electrograms from those made daily during the Carnegie's seventh cruise from August 1928 to November 1929. The results, arranged in three-month seasonal groups, show remarkable agreement with those obtained on the earlier cruises of the Carnegie, substantiating the conclusion drawn from them that the atmospheric potential, when freed from local effects, has a principal 24-hour term which varies in the same way and at the same time over the whole Earth, with maximum occurring earlier in the Greenwich day in December than in June and with amplitude greater in March than in June.

The photographic observations of deflections of radio waves from the Kennelly-Heaviside layer give increasing evidence of the fundamental importance of the phenomena of terrestrial magnetism in this method of investigating the upper atmosphere. Further possibilities in radio investigations for the study of solar and terrestrial correlations have been supplied by provision to install, at both the Watheroo and Huancayo observatories, radio transmitting- and receiving-stations for the study of short-wave propagation, of plane of polarization of incoming short-waves, and of interrelation of short-waves with magnetic and atmospheric-electric elements. The construction of photographically recording-apparatus, following designs of the United States Bureau of Standards, to make continuous record of the height of the layer is under way. It is planned to install recorders of this type within the next year at the two observatories, thus providing data at widely separated stations for the study of the diurnal movements of the layer.

L. R. Hafstad and M. A. Tuve (17) have discussed observations of the height of the Kennelly-heaviside layer made during the magnetic disturbance of October 17 to 19, 1928, and show an unusually great effective height and a change in echo-pattern during this disturbance. The Department's researches on this subject include collaboration with a number of investigators, including A. H. Taylor of the United States Naval Research Laboratory, P. A. de Mars and G. W. Kenrick of Tufts College, the staff of the United States Bureau of Standards, H. T. Stetson of the Perkins Observatory, Howell C. Brown of Pasadena, California, and G. W. Pickard, the last named a research associate of the Institution.

Experiments on the penetrating radiation ('cosmic rays') utilizing the multiple coincidences of Geiger-Muller tube-counters (18) have been made by M. A. Tuve, L. R. Hafstad, and O. Dahl. The distribution of the hard components with respect to azimuth has been more carefully determined, giving approximately a sine-square curve. Perhaps the most interesting experiment has been the use of the multiple counters as a 'penetrating-radiation telescope' directed at the Sun during certain hours of the day. No evidence has so far been obtained of the one-half per cent solar component of the hard rays recently announced by Hess. An endeavor has also been made to construct a 'light-counter,' which would be sensitive in the visible region. The 'light-counter' is a tube-counter provided with a window and a photo-electric surface, as devised by Rajewsky, and it has an advantage over the ordinary photo-electric cell, for measurements of very weak light, corresponding to the detection of several electrons per minute in comparison with the detection of the weakest currents of a photo-electric cell. Cadmium-surfaced

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counters are readily made to give an extremely great sensitivity in the ultra-violet, and if a suitable counter can be made for the visible it may be of considerable importance, for example, to astronomical measurements. These experiments are in progress.

In addition to the terrestrial magnetic, electric, and meteorological observations at the Department's Watheroo and Huancayo observatories, cooperation insuring the maintenance of the atmospheric-electric program at Apia has been continued, and both atmospheric-electric and earth-current installations have been made through cooperation with the United States Coast and Geodetic Survey and the American Telephone and Telegraph Company at the Tucson Magnetic Observatory. In cooperation with the Mount Wilson Observatory of the Carnegie Institution of Washington, spectro-helioscopes for daily eye-observations of the solar conditions and activity are being installed at the Watheroo and Huancayo observatories. In cooperation also with the United States Coast and Geodetic Survey and through the generous assistance of the Rockefeller Foundation, it has been possible to secure for the Alaska Agricultural College and School of Mines the equipment and maintenance funds for a five-year operation of a first-class auroral station at College near Fairbanks, Alaska.

With the inauguration August 1, 1930, by Science Service of the daily URSI broadcast, sponsored by the American Section of the International Scientific Radio Union with the cooperation of the United States Coast and Geodetic Survey, the Mount Wilson Observatory, the Smithsonian Institution, the United States Bureau of Standards, the United States Army, the United States Navy and the Alaska Agricultural College and School of Mines, there will soon be a considerable addition to the data involving solar and terrestrial relationships. These data are being summarized and published regularly in the 'Journal of Terrestrial Magnetism and Atmospheric Electricity', as are also quarterly summaries of the provisional Wolfer sunspot-numbers, and details of the principal magnetic storms recorded at the Sitka, Cheltenham, Tucson, Honolulu, Huancayo, and Watheroo observatories.

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ZUR OZONFRAGE DER TIEFEREN ATMOSPHÄRENSCHICHTEN

von

F.W. Paul Götz und Rudolf Ladenburg.

Im 2. Heft dieser Berichte (1929) sind Parallelmessungen der hohen Ozonschicht in zwei Höhenlagen der Alpen (Arosa 1860 m-Chur 600m) veröffentlicht. Je nach Annahme eines Trübungsfaktors T (Definition Linke) der Zwischenschicht Chur-Arosa ergaben sich für die 1260 Meter Luftstrecke:

T.	O_3 in cm
1,0	0.004
1,3	0.002
1,7	0.000
2,0	0.002

T-Werte waren nicht verfügbar. Es wurde so geschlossen, dass optisch innerhalb der bisherigen Messgenauigkeit ein Ozongehalt der bodennahen Luftschichten nicht nachzuweisen sei. Inzwischen liegt nun auch für Ultraviolett der Trübungsfaktor über Arosa aus grossem Material vor[1]; im Jahresmittel ist T=1,16.

Die uns von der Pariser Ozonkonferenz übertragene weitere Untersuchung haben wir nun mit der schärferen Methode der Spektralphotometrie einer an kurzwelligem Licht reichen Lichtquelle anstelle der Sonne im Frühjahr 1930 oberhalb Arosas aufgenommen[2]. Das Spektrum einer in 1900 m Seehöhe aufgestellten Quecksilberlampe wurde mittels zweier Spektrographen ohne Kollimator aufgenommen; der eine stand abwechselnd in 4,8 km. Distanz auf 2500 m Seehöhe und in 1,2 km Distanz auf 2020 m Höhe; der andere stand dauernd an der letzteren Stelle. Untersucht wurden so 3,6 km Luftstrecke einer mittleren Seehöhe von 2300 m. Für ein km Luftstrecke ergab sich aus allen Wellenlängen bis herunter zu 2540 Å dieselbe Ozonmenge von 0.0035 cm (Absorptionskoeffizienten nach Fabry-Buisson), was der Grössenordnung der alten chemischen Messungen nach der Methode des Observatoriums Montsouris entspricht. Unterhalb 2540 Å kommt noch eine starke anderweitige Absorptionsursache hinzu (O_2?). Die Messungen der Herren Buisson, Jausseran und Rouard[3] in 300 m Höhenlage der Provence scheinen unserer Meinung nach dieselbe Deutung zuzulassen (O_3 = 0,0024).

Ergänzungen von P. Götz: Der vorstehende Ozonnachweis harmoniert mit Ergebnissen[1] meiner Spitzbergenexkursion 1929: nach ihnen muss Ozon auch in denjenigen tieferen Atmosphärenschichten vorhanden sein, die an der Zerstreuung des Himmelslichts beteiligt sind; aus dem Intensitätsgang des Zenithlichts dürfte sich so die vertikale Verteilungskurve des Ozons errechnen lassen. In Spitzbergen hat sich weiter eine einfache Methode[4] bewährt, einen annähernden Wert des Ozongehalts einfach aus der kürzesten Wellenlänge zu entnehmen: die Methode dürfte sich vor Mond auch fürs internationale Polarjahr empfehlen. Als bislang kürzeste Wellenlänge des Sonnenlichts uberhaupt ist in Arosa mit 3-stündiger Exposition des Aroser Ultraviolettspektrographen[5] 2863 Å[4] erreicht. Von weiteren Arbeiten sei noch an die Nachtmessungen von Chalonge[6] erinnert. Das Lichtklimatische Observatorium Arosa hofft, seine klimatische Begünstigung auch künftig möglichst umfangreich in den Dienst der Ozonforschung stellen zu dürfen.

AROSA. März, 1931.

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NOTE ON THE TEMPERATURE OF THE UPPER ATMOSPHERE.

By E. H. Gowan.

Since the publication of the Second Report another year has been spent on the calculations of upper atmosphere temperatures: the results are published in Proc. Roy. Soc., Vol. 128, A. 808, Aug. 1930, pp. 531-550. Better values of the coefficient of absorption of water-vapour were adopted. Account was taken of the effect on absorption and radiation of the diffuseness of the terrestrial and atmospheric radiation as contrasted with the parallel solar radiation. The labour involved in the calculation was reduced by the adoption of optical thicknesses of layers: the ensuing uncertainty in the actual heights was shown to be of little importance.

In the first instance the distribution of water-vapour above the tropopause was assumed to be that due to diffusion equilibrium. It has been shown, however, that a limited amount of convection is possible without much deviation from the temperatures as governed by radiation. This small convection, which seems to be called for by observations of various kinds on winds in the stratosphere, would be sufficient to keep the atmosphere mixed, since the diffusive settling out is very slow. Consequently the water-vapour present may be much less than would be the case with diffusion equilibrium.

A large discrepancy between the infra-red absorption coefficients of ozone as measured by Ladenburg and Lehmann in the laboratory, and by K. Angstrom in the solar spectrum has been pointed out. Also A. Anstrom has claimed that the ozone will have to radiate, unaided, all the energy that it absorbs, and that radiation by the water-vapour as well is inadmissible.

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Calculations have been made showing the effects on the temperatures of all the above-mentioned facts and possibilities. The general conclusion drawn is that above 60 km. temperatures of the order of over 500° absolute are possible. At the reigning pressures this temperature would not too greatly accelerate the decomposition of ozone. It gives densities agreeing very well with those calculated by Lindemann and Dobson from meteor data. The necessary gradient from 30 to 60 km. gives adequate grounds for the explanation of the refraction of sound waves in this region solely by the temperature increase in velocity. An interesting point is the calculation of the temperature of the auroral region from Babcock's measurements of the width of the green line 5577 A.U. The source seems to be oxygen, and assuming the widening to be due entirely to the Doppler effect, a temperature of the order of 900° absolute results. This is therefore a maximum, and is appropriate perhaps to the region of greatest auroral frequency, i.e. about from 85 to 150 km. An attempt is being made to see to what extent this line width is sensitive to changes in temperature and pressure, and may lead to more reliable estimates of the temperature by this method. Should this turn out to be possible, its application to polar aurora of various heights ought to yield most interesting results.

With respect to any further calculations I consider that the available data do not justify the application of more refinements. There remains, however, the question of annual and diurnal variations of upper air temperatures. Analysis of the heights of appearance and disappearance of the meteors observed in England gave an uncertain indication of a diurnal effect, i.e. a drop in temperature during the night. I am at present seeking more extensive observations of as reliable a character as those taken by Mr. F. W. Denning and his co-workers. Any help in locating lists of doubly observed meteors from which the heights of appearance and disappearance have been, or can be, calculated would be appreciated.

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March, 1931.

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DISCUSSION OF THE GREENWICH SOLAR AND MAGNETIC DATA.

By W.M.H. Greaves.

In the last Report of the Commission on Solar and Terrestrial Relationships, reference was made to a discussion, then proceeding, of the Greenwich Solar and Magnetic Data, and an account was given of a paper which represented the first step in the examination of the material. This paper dealt with a restricted list of 60 large magnetic storms, and it was found that these large storms were associated with large Sunspots more often than could be ascribed to chance.

In a subsequent paper* a more extended list of 403 storms has been examined. This catalogue comprised all magnetic disturbances which occurred over the period 1874 April (when systematic solar observations were begun at Greenwich) to 1924 December, and for which the ranges exceeded 30' in Declination, or 150γ in either of the other elements. It has been published as an appendix to the Greenwich Photoheliographic Observations for 1927.

On plotting against each year the number of catalogued storms which took place in it, it was at once seen that the eleven year period manifested itself in the frequency of the storms. A detailed analysis was then undertaken with the object of investigating to what extent the occurrence of individual storms was associated with an increase of spot activity. For this purpose the storms were divided into seven classes according to the ranges in the magnetic elements, and a further class of 'quiet days' was added for comparison. The Sun's disc was divided into two zones, one comprising the central longitudes of the disc, and the other made up from the east and west limbs. In each zone the spot of largest mean area (the measured areas having first been corrected for foreshortening) which was on the disc at the time of commencement of each storm, was catalogued, and the mean areas were averaged for the two zones and the eight classes as shown in the following Table. Fuller details are given in the paper. The last two classes are made up of the Great Storms/ previously discussed. The areas are given in millionths of the Sun's hemisphere.

Mean Areas of Largest Spots at Times of Commencement of Storms.

Limits of Storm.	Spots near Centre of Disc, 53°E to 53°W.	Spots near Sun's Limbs, 53° to 79° E and W.
Quiet Days.	244	167
< 120γ	260	181
120-150γ	273	159
150-180γ	329	220
180-210γ	390	302
> 210γ	462	189
Great Storms	691	251
Very Great Storms.	1116	181

* W.M.H. Greaves and H.W. Newton. Monthly Notices R.A.S. 89. 84, November 1928.

/ i.e. Storms for which the ranges exceeded one degree in declination or 300γ in either of the other elements. The 'Very Great Storms' comprise those for which the ranges were known to exceed 90' in declination or 500γ in one of the other elements.

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It seems clear that there is a definite tendency for large spots to be in evidence in the central regions of the disc at the times of the occurrence of the larger storms.

A more detailed investigation indicated that the correlation was confined to an area of the solar disc extending from about 26° heliographic longitude east of the central meridian to about 52° west. It was pointed out that the evidence was consistent with the 'solar stream' theory of the origin of magnetic storms, and suggested an interval of the order of one and a half days for the time taken by the stream to travel from the Sun to the Earth.

At the same time a number of cases were listed in which storms had taken place when there were no spots on the visible disc. The evidence is in accord with the hypothesis that storms have their origin in some type of solar disturbance, and indicates that the more intense of such disturbances tend to be associated with large spots, but the occurrence of storms on spotless days proves that the disturbances in question cannot be identified with spots.

In a further paper* the catalogue of storms which had been prepared was examined for the purpose of investigating whether they confirmed the well known 27 day recurrence tendency. The storms were divided into groups according to their ranges as before, and it was found that:-

(1) For the 60 great storms and for 88 other storms of mean range greater than 180γ there was no clear tendency for a further storm to follow 27 days later.

(2) 91 storms of mean ranges between 180γ and 150γ showed a marked 27 day wave but no 54 day wave.

(3) For 91 storms of mean range between 150γ and 130γ and for 73 storms of mean range less than 130γ both the 27 day and 54 day waves were clearly shown.

It was concluded that the recurrence tendency is mainly a property of the less intense storms.

In conclusion the Greenwich data are in accord with the hypothesis that magnetic storms are caused by streams issuing from some type of solar disturbance, and indicates that these disturbances possess the following properties -

(1) Their frequency follows the eleven year cycle.

(2) The more intense disturbances tend to be associated with the larger spots.

(3) Some of these disturbances (those responsible for the smaller storms) may persist for several solar rotations.

There also appears to be a suggestion that the more intense disturbances are comparatively short-lived. Alternatively/ the absence of the recurrence tendency for the larger storms may mean that the streams producing them are more compact and may more easily miss the earth on their return 27 days later.

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* Monthly Notices 89, 641, May 1929.

/ As was suggested by Professor S. Chapmen on the occasion when the paper was read. The larger magnetic storms are of comparatively short duration, and this circumstance shows that the streams producing them are more compact.

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REVIEW OF CERTAIN CONTRIBUTIONS TO SOLAR AND TERRESTRIAL MAGNETISM.

By Ross Gunn.

Investigation of the paths of ions and electrons which move about in electric and magnetic fields under the influence of thermal agitation has shown that certain effects are produced which have important bearing on terrestrial and solar problems.

An early paper[1] showed that when ions immersed in crossed electric and magnetic fields execute long free paths the ion motions are such that:

(a) the electrical conductivity is abnormally low.

(b) the region is highly diamagnetic.

(c) both kinds of ions are swept in the same direction at right angles to both fields with the same velocity and constitute a mass movement of the ionized region.

In a following paper[2] the study was continued and it was shown that in an inhomogeneous magnetic field the ion motions were such

(d) that an electric current was produced which reduces the magnetic inhomogeneity.

The physical reality of certain of these effects has been questioned by Cowling[3] who thinks that boundary effects may reduce the diamagnetic effect to zero if the ionized region is in thermal equilibrium. The diamagnetic effects of the solar and terrestrial atmosphere are preponderantly due to ions and Cowling's criticisms which are of the same general nature as those of Van Leeuween[4] do not apply[10]. It is interesting to note that even in the case of metals where Van Leeuween's and Cowling's remarks apply, if they apply anywhere, a diamagnetic effect is still predicted when the problem is completely treated[5,6]. Cowling[3] has raised an important objection to the existence of ion drifts due to gravitational forces and extended it (without careful examination) to the case of an inhomogeneous magnetic field. Cowling shows that if the ionized region is in gravitational and thermal equilibrium, pressure gradients give rise to forces which just balance the gravitational forces. However, differential effects still exist which arise from a non-steady state such, for example, as might exist in a sunspot. Thus, there is good reason to believe that (d) is important under special conditions.

The electromagnetic effects discussed above have been applied to terrestrial and solar problems. The solar diurnal variations of terrestrial magnetism seem incapable of explanation on the old dynamo theory due to effect (a) and the existence of effect (b) led to the diamagnetic theory of these variations. This theory accounts satisfactorily for the observed features of the variation [1,7] including the advance of phase of the horizontal component[8]. The effect of diamagnetism in the solar atmosphere and its part in limiting the solar magnetic field of the sun has been studied[9] and diamagnetism has been shown to explain quantitatively the observed magnetic distribution. Moreover, the study led to a method of estimating approximately the solar atmospheric pressure as a function of altitude and the mean atomic weight of the solar atmospheric ions.

The third effect (c) discussed above is of particular importance in the sun since the mechanism is such as to relate

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electromagnetic phenomena with mechanical effects and these are more readily observed on the sun than the electrical and magnetic quantities. The mass movement of the ionized solar atmosphere which results from crossed electric and magnetic fields has been shown to account for the observed anomalous rotation of the sun[10]. It is shown that the observed change in rotational period of the sun with latitude and with altitude arises from changes in the ratio of the electric to magnetic field intensities. The observed variations take place only in the solar atmosphere and it is pointed out that the only observed solar rotational period which may be expected to be constant is the period of rotation of the magnetic pole. The observed motions require that the sun possess a radial electric field strikingly similar to that observed on the earth. The origin of the electric field is not definitely known but the potential difference between the sun proper and the outer space is of the order of 10^7 volts and the electric field in a typical region of the reversing layer is 0.013 volts/cm. The observed motions require a negative charge on the sun proper (presumably a surface charge) and a positive volume charge in the solar atmosphere. The effect of changes in the total solar radiation is considered and it is shown[11] that these changes must be accompanied by changes in the apparent solar rotation. The variations are actually observed. The electric current necessary to maintain the solar electric field is calculated and it is found that the total electrical energy dissipated in the solar atmosphere is an appreciable fraction of the total radiated energy. In a later paper[12] on the solar rotation, it was shown that if the observed anomalous rotation of the sun is an atmospheric phenomenon, then angular momentum must be constantly added to the sun proper by the electromechanical atmospheric motion. If the sun were initially at rest the present angular momentum is shown to be accounted for by the mechanism. Such an electromechanical mechanism for constantly adding angular momentum to stellar systems seems important in understanding the evolution of these systems.

An attempt has been made to account for the tremendous magnetic fields of sunspots[13] and at the same time postulate a nearly neutral conducting region in and around the spot. The magnetic field associated with a spot is believed to have its origin in electric currents produced in the solar atmosphere by drift currents arising from a self produced inhomogeneous magnetic field. The theory is satisfactory in being adequate to account for the observed magnitudes and if the radial curvature of the spot is taken into account the maximum field is roughly proportional to the radius and therefore agrees with observation. In certain details the theory is incomplete and more thought is being devoted to the problem.

Certain other terrestrial and solar magnetic problems have to do with short free path ion motions, such as take place inside the sun and earth. A theory of the permanent magnetic fields of the sun and earth has been proposed[14] in which the fields arise from a system of electrical currents which flow in rings around the axis of spin of the body. The current sheets are produced by the interaction of the thermal motions of the ions or electrons with crossed electric and magnetic fields. The magnetic field is related primarily to the radial and axial symmetry of the body and does not depend on rotation. It is of interest to note that this theory is apparently the only theory thus far proposed which satisfies Bauer's criterion[15] for a possible explanation of the observed permanent magnetic fields.

Studies of the magnetic effects due to the contraction of the sun and earth show that electromagnetic forces are important in these bodies[16,17] and that earth movements may produce secular magnetic variations. An important conclusion

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of this study was that the conductivity of the earth's core was very large and could not be inferred from diurnal magnetic variation data, but must be determined from the physical properties of the core.

In a forthcoming paper the electrical state of the sun is discussed and it is shown that (a) the annihilation of charge inside the sun is improbable (b) the net solar electrical charge cannot exceed 1 coulomb.

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U.S.A.

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SUR LES PROPRIÉTÉS DES GAZ IONISÉS ET LA PROPAGATION DES ONDES RADIOTÉLÉGRAPHIQUES DANS LA HAUTE ATMOSPHÈRE.

par C. Gutton,
Directeur du Laboratoire
National de Radioelectricité
et

H. Gutton,
Ingénieur aux Etablissements
MICHELIN.

Nous avons exposé il y a deux ans[1], les résultats d'expériences de laboratoire sur les propriétés diélectriques des gaz ionisés dans les champs électromagnétiques de haute fréquence. Les phénomènes observés s'expliquent, comme nous l'avons montré, en admettant que les électrons d'un gaz ionisé ne sont pas entièrement libres comme le suppose la théorie de ECCLES, mais sont sollicités par une force de rappel qui tend à les ramener vers leur position moyenne lorsqu'ils en sont écartés. L'existence de cette force de rappel entraîne celle d'une période d'oscillation libre de l'électron et de phénomènes de résonance lorsque la période du champ électromagnétique dans lequel se déplace l'électron coincide avec la période propre de ce dernier.

Cette force de rappel résulte des actions mutuelles des électrons et des ions positifs. Une théorie développée par TONKS et LANGMUIR[2] montre l'existence possible d'une période propre d'oscillation électronique dans un gaz ionisé.

Depuis la publication du précédent rapport, nous avons repris et varié nos expériences[3] et nous nous proposons d'indiquer dans les lignes qui suivent les résultats expérimentaux que nous avons obtenus.

Afin de pouvoir repérer l'intensité d'ionisation du gaz, nous avons scellé, dans la paroi du tube T (fig.1) contenant le gaz ionisé, aux extrémités d'un diamètre, deux fils de platine a et b entre lesquels on établit, avec une batterie d'accumulateurs E, une différence de potentiel constante égale à 4 volts. Un galvanomètre G mis en circuit mesure l'intensité du courant qui traverse le gaz entre ces électrodes. Cette intensité, proportionnelle à la conductibilité du gaz, sert à repérer la grandeur de son ionisation.

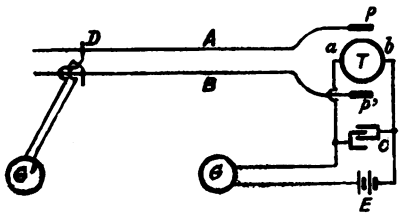

Fig. 1.

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1. Deuxieme rapport de la Commission, p. 70, 1929.
2. TONKS et LANGMUIR, Phys. Rev. Février 1929, p. 195.
3. H. GUTTON, Annales de Physique, Janvier 1930, p. 62.
   C. GUTTON, Annales de Physique, Juillet-Août 1930, p.5.

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Nous avons d'autre part un peu modifié le dispositif expérimental des premières expériences.

Le tube de verre T dont l'axe est vertical à 30 cm. de longueur et 3,93 cm. de diamètre intérieur. Deux anneaux de papier d'étain, collés à une distance de 21,1 cm. sur le paroi extérieure du tube servent à ioniser le gaz en y faisant passer une décharge à fréquence beaucoup plus basse que celle pour laquelle nous nous proposons d'étudier les propriétés diélectriques. Ces décharges étaient produites par un oscillateur à lampes, leur longueur d'onde était 90 mètres, tandis que les ondes les plus longues pour lesquelles nous avons étudié les propriétés du gaz n'avaient que 4,83 m. Nous avons vérifié que les ondes longues étaient sans influence sensible sur les appareils en résonance sur les ondes courtes.

De part et d'autre du tube et à 6,9 cm. de distance sont disposées deux plaques de cuivre pp' de 2,6 cm^2 de surface. Elles sont respectivement soudées aux extrémités des deux fils AB d'une ligne sur laquelle on peut déplacer un pont P au milieu duquel est intercalé une soudure thermoélectrique reliée à un galvanomètre G'.

Un oscillateur à ondes courtes placé au voisinage de la ligne y induit une force électromotrice d'amplitude et de fréquence constantes.

Le gaz n'étant pas ionisé, on accorde la ligne sur cet oscillateur en déterminant la position du pont pour laquelle le galvanomètre G' relié à la soudure indique un courant d'intensité maximum.

On ionise ensuite le gaz dans le tube en y faisant passer des décharges, la position d'accord du pont est modifiée, on la détermine à nouveau et on mesure l'intensité du courant de résonance. On détermine d'autre part, le courant qui passe entre les électrodes auxiliaires a et b et qui est proportionnel à la conductibilité du gaz.[1].

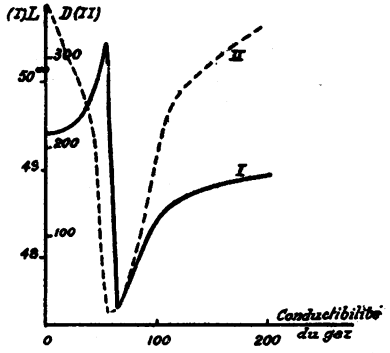

Fig. 2.

1. Il importe, lors de cette mesure, de s'assurer qu'il n'y a pas de courant détecté par le gaz à cause d'une dissymétrie des électrodes. On supprime ce courant en réglant la position du circuit de ces électrodes de façon à ce que les oscillateurs n'y induisent pas de force électromotrice et que le galvanomètre G reste au zéro lorsqu'il n'y a pas d'accumulateurs en circuit. On obtient plus facilement ce résultat en disposant en dérivation sur les électrodes A et B un condensateur G de grande capacité.

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En portant en abscisses la conductibilité du gaz repérée par la déviation du galvanomètre G, en ordonnées les longueurs de résonance L de la ligne, on obtient pour des ondes de 2,487 m. de longueur, la courbe I de la figure 2.

En portant en ordonnées les déviations du galvanomètre G', qui sont proportionnelles au carré de l'intensité efficace du courant de résonance on obtient la courbe II.

La courbe I montre qu'en augmentant l'ionisation, on observe d'abord une augmentation de la longueur L de résonance de la ligne, ce qui est l'indice d'une diminution de la capacité constituée par les deux plaques et par suite de la constant diélectrique du gaz ionisé.

On atteint ensuite une ionisation pour laquelle la longueur L cesse de croître puis, pour une très faible augmentation d'ionisation diminue beaucoup, pour atteindre une valeur minimum. Elle croît ensuite et devient constante pour les faibles ionisations. Il est donc une ionisation pour laquelle la constante diélectrique passe brusquement d'une valeur inférieure à celle du gaz non ionisé à une valeur très supérieure.

D'autre part la courbe II, montre que lors de cette ionisation critique l'amortissement des oscillations du circuit accordé devient considérable, ce qui est l'indice d'une absorption d'énergie dans le gaz.

Ces résultats corcordent avec ceux que nous avions déjà obtenus par une méthode différente et que nous avons exposés dans notre précédent mémoire.

En répétant ces expériences pour des longueurs d'ondes différentes, on retrouve des courbes analogues à celles que nous venons de décrire, mais la conductibilité du gaz pour laquelle se produit une brusque variation de la constante diélectrique est d'autant plus petite que l'onde est plus longue. Le tableau suivant donne pour quatre longueurs d'onde les valeurs correspondantes de la conductibilité C correspondant au changement brusque de constante diélectrique.

λ	C	$\lambda^2 C^{3/4}$
483 cm.	9	121×10^4
252 cm.8	48	116×10^4
183 cm.4	111	116×10^4
132 cm.4	296	124×10^4

Le produit $\lambda^2 C^{3/4}$ est à peu près constant.

Toutes les expériences ont été faites à une pression, mesurée à la jauge, de quelques dix millièmes de millimètre, inférieure à la tension de vapeur du mercure de la jauge.

Aux pressions plus élevées, la variation de constante diélectrique est moins brusque et de plus petite amplitude.

Des expériences en cours nous montrent qu'en disposant les deux plaques p et p' à l'intérieur du tube, on obtient les mêmes phénomènes, avec des variations beaucoup plus grandes de la longueur L de la ligne, sous la condition d'opérer à des pressions aussi basses que possible.

Dans le cas des plaques extérieures au tube la conductibilité pour laquelle se produit la brusque variation de constante diélectrique est indépendante de la distance de ces plaques à la paroi du tube. Il s'agit donc bien d'un phénomène indepéndant

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de la disposition expérimentale utilisée pour l'observer.

Nous avons déjà montré, dans le précédent mémoire publié par la Commission d'Etudes solaires que ces phénomènes s'expliquaient par l'existence d'une période de résonance des électrons du gaz et montre le rôle de ces résonances lors de la propagation dans la haute atmosphère des ondes radiotélégraphiques.

Nous ne reviendrons pas sur ce sujet et décrirons maintenant des expériences montrant que ce sont les mouvements des charges électroniques qui interviennent.

Lorsqu'on dispose le tube T à l'intérieur d'une bobine parcourue par un courant constant, de façon à faire agir sur le gaz un champ magnétique normal à la direction des vibrations électroniques et que l'on répète les mêmes expériences, on trouve un dédoublement de la période de résonance. Pour deux ionisations différentes, l'une supérieure, l'autre inférieure à celle qui correspond à la résonance en l'absence de champ, la courbe obtenue (courbe I, fig. 3), relative comme celle de la figure 2 à des ondes de 2,487 m. de longueur, indique deux variations brusques de la constante diélectrique. La courbe II montre qu'elles correspondent chacune à un maximum d'absorption. L'intensité du champ magnétique était 21,5 gauss.

La période de résonance du gaz a été dédoublée. Par un calcul analogue à celui qui détermine dans l'effet ZEEMANN le dédoublement d'une raie d'absorption, on peut déduire de l'écart mesuré le rapport de la charge à la masse de la particule oscillante, on trouve en unités électromagnétiques 1,68 x 10^7, valeur très voisine de celle qui correspond à l'électron.

Des mesures sur des longueurs d'ondes variées confirment ce résultat.

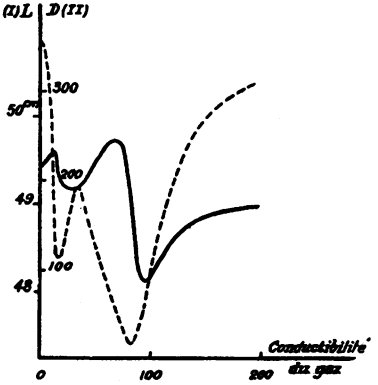

Fig. 3.

Nous rendrons compte maintenant d'expériences un peu différentes qui montrent également l'existence d'une résonance électronique.

Le tube à décharge T n'étant plus entre les plaques p et p' on dispose dans son voisinage un oscillateur de longueur d'onde égale à quelques mètres qui crée dans le gaz ionisé un champ électromagnétique de fréquence élevée. Pour diverses ionisations, on mesure successivement la conductibilité C_0 du gaz en l'absence du champ de haute fréquence, puis la conductibilité C, lorsque faisant fonctionner l'oscillateur on fait agir le champ sur le gaz.

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On constate que pour les ionisations très faibles ou très fortes, la conductibilité n'est pas modifiée par la présence du champ et la courbe (fig. 4) obtenue en prenant comme abscisse C_0 et comme ordonée C se confond avec une droite inclinée à 45°. Mais il est une ionisation bien définie pour laquelle la conductibilité du gaz est très augmentée et la courbe à une partie verticale A.

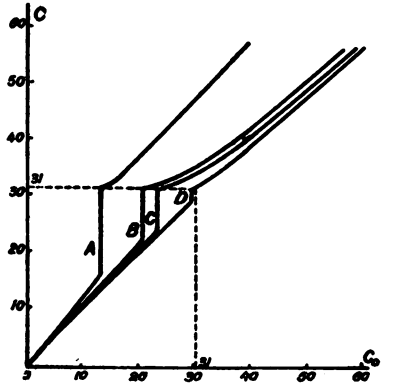

Fig. 4.

Lorsqu'en éloignant l'oscillateur du tube, on diminue l'intensité du champ, cette partie verticale devient de plus en plus courte et finit par disparaître, ainsi que le montrent les courbes B C D de la figure 4.

Si reprenant sur le même tube les expériences que nous avon décrites au début, on détermine la conductibilité pour laquelle se produit la variation brusque de la constante diélectrique, on observe que toutes les parties supérieures des segments de ligne droite des courbe ont une ordonnée commune égale à cette conductibilité. C'est aussi à elle qu'est égale l'abscisse limite pour laquelle le segment de droite se réduit à une longueur nulle.

Ces phénomènes s'expliquent très facilement dans l'idée d'une résonance.

En effet, lorsque l'ionisation primitive est très faible et très éloignée de celle qui correspond à une résonance, l'amplitude des oscillations électroniques est faible, leur vitesse n'est pas suffisante pour produire un supplément d'ionisation. Mais lorsqu'on approche de l'ionisation pour laquelle il y a résonance, les amplitudes et les vitesses des oscillations électroniques augmentent assez pour produire une ionisation supplémentaire. Cette ionisation rapproche encore le gaz de la résonance et croît nécessairement jusqu'à ce que cette dernière soit atteinte. Ainsi s'explique l'ascension verticale de la courbe. Lorsque l'ionisation primitive est beaucoup plus intense que celle pour laquelle il y a résonance, les vibrations électroniques reprennent dans le champ de haute fréquence des amplitudes très petites. L'ionisation n'est pas augmentée et la courbe tend à nouveau vers une droite inclinée à 45°.

Si le champ électromagnétique est d'intensité assez petite pour que l'ascension brusque de la courbe ne se produise que lors de l'ionisation qui correspond à la résonance, toute partie rectiligne de la courbe disparaît.

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La forme des courbes de la figure 4 s'explique donc très bien dans l'idée d'une résonance et la conductibilité qui correspond à la résonance sur une période donnée est la même que celle que détermine l'étude des variations de la constante diélectrique.

Enfin nous indiquerons comment on peut constater la résonance électronique du gaz par une méthode tout à fait identique à celle qui sert à accorder un résonateur et un oscillateur.

Disposons un oscillateur à ondes courtes au voisinage du tube T et intercalons sur le circuit de cet oscillateur un ampéremètre thermique ou une petite lampe à incandescence qui permettent de juger de l'amplitude de ses oscillations.

Augmentons lentement l'ionisation du gaz dans le tube T, nous constatons que l'on passe par une ionisation bien définie pour laquelle le gaz prend beaucoup d'énergie à l'oscillateur ce qui fait considérablement baisser l'amplitude de ses oscillations. C'est exactement ce que l'on observe lorsqu'on accorde un résonateur disposé au voisinage d'un oscillateur.

Toutes les expériences que nous venons de décrire, comme celles qui ont fait en 1929 l'objet d'un rapport à la Commission d'études des relations entre les phénomènes solaires et terrestres, concordent donc à montrer l'existence de phénomènes de résonance dans les gaz ionisés. Les particules en résonance sont, comme le montre l'expérience, les électrons. Des recherches faites en employant des tubes de diamètre très variés ne nous ont pas conduit à constater que l'ionisation correspondant à une fréquence donnée dépend des dimensions du tube.

Nous avons déjà montré comment l'existence de cette résonance intervenait pour déterminer les conditions de propagation des ondes radiotélégraphiques autour de la Terre.

L'existence d'une résonance crée dans l'atmosphère ionisée par les radiations solaires des couches sur lesquelles se produisent des réflexions du même genre que les réflexions métalliques. La fréquence de résonance étant d'autant plus grande que l'ionisation est plus intense, la couche réfléchissante doit être d'autant plus élevée que les ondes sont plus courtes. C'est bien le résultat donné par les mesures de hauteur de cette couche. Si les ondes sont si courtes que l'ionisation à toute altitude est inférieure à celle qui correspondrait à la résonance, ces ondes ne sont plus réfléchies et peuvent se propager hors des limites de la haute atmosphère terrestre.

COOPERATIVE RESEARCH WITH THE SPECTROHELIOSCOPE.

by G. E. Hale.

As the spectrohelioscope affords a very satisfactory method of observing bright and dark flocculi on the sun's disk, as well as prominences at the limb, an inexpensive outfit has been devised, which includes a small coelostat telescope. Twenty-five complete instruments of this type have been built or ordered and many of these are already in operation at the widely distributed observatories and laboratories named in the accompanying table.

The use of this method for the study of various solar phenomena is being described in a series of articles by Hale on

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'The Spectrohelioscope and its Work'[1]. The third article, entitled 'Solar Eruptions and their Apparent Terrestrial Effects', will soon be published. These eruptions on the sun's disk are usually of comparatively short duration and therefore are rarely seen or photographed at more than one observatory. As they may prove to be the cause of exceptional auroras and intense magnetic storms, it is important that the sun be examined at frequent intervals so that all of their phases may be recorded. A co-operative plan of observation, primarily concerned with such eruptions but also including other phenomena, should therefore be prepared in harmony with the general scheme of solar research of the International Astronomical Union.

Spectrohelioscopes.

Observatory.	Place.	Latitude.	Longitude.
Royal	Greenwich, England.	+51° 29'	$0^h\ 0^m$
Solar Physics	Cambridge, England.	+52 13	0 0
Helvetic	Zurich, Switzerland.	+47 23	- 0 34
Astrophysical	Florence, Italy.	+43 45	- 0 45
American College	Beirut, Syria.	+33 54	- 2 22
Solar Physics	Kodaikanal, South India.	+10 14	- 5 10
Department of Terrestrial Magnetism of the Carnegie Institution of Washington.	Watheroo, Australia.	-30 18	- 7 44
National Institute of Astronomy.	Nanking, China.	+32 07	- 7 55
Commonwealth Solar Observatory.	Canberra, Australia.	-35 20	- 9 56
Dominion	Wellington, New Zealand.	-41 17	-11 39
Apia	Apia, Samoa.	-13 48	+11 27
Mount Wilson, Carnegie Institution of Washington.	Mount Wilson, California.	+34 13	+ 7 52
Mount Wilson, Carnegie Institution of Washington.	Pasadena, California.	+34 13	+ 7 52
Pomona College	Claremont, California.	+34 6	+ 7 51
University of South Dakota.	Vermilion, South Dakota.	+42 42	+ 6 28
Yerkes	Williams Bay, Wisconsin.	+42 34	+ 5 54
Adler Planetarium.	Chicago, Illinois.	+41 50	+ 5 51
Ohio State University.	Columbus, Ohio.	+40 0	+ 5 32
Department of Terrestrial Magnetism of the Carnegie Institution of Washington.	Huancayo, Peru.	-12 3	+ 5 01
Vassar College (Physical Laboratory)	Poughkeepsie, New York.	+41 41	+ 4 56
Bell Telephone Laboratories.	New York City, New York[2].	+40 45	+ 4 56
Massachusetts Institute of Technology (Physical Laboratory.	Cambridge, Massachusetts	+42 23	+ 4 44

1. Part I. 'History, Instruments, Adjustments, and Methods of Operation', Mt.Wilson Contr.,No. 388; Astrophysical Journal, 70,265, 1929.
   Part II. 'The Motions of the Hydrogen Flocculi near Sun-spots', Mt.Wilson Contr., No. 393: Astrophysical Journal, 71, 55, 1930.
2. This instrument will probably be erected at a site several miles from the Bell Telephone Laboratories in New York City.

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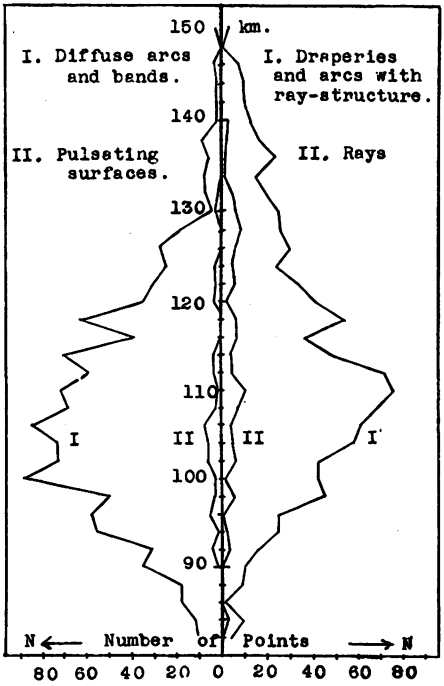
MEMORANDUM ON INVESTIGATIONS ON AURORA AT NORDLYSOBSERVATORIET, (AURORAL OBSERVATORY), TROMSØ.

by Leiv Harang.

During the last two years a great number of parallactic photographs of the different types of the aurorae have been taken at Tromsø. In collaboration with Mr. E. Tønsberg the height of 659 aurorae (2722 points lying on the borders of the aurorae) have been calculated, using the methods developed by Størmer. The results of the height-measurements of the lower border of the different types of the aurorae are evident from the frequency-curves in fig. 1.



The frequency-curves of the diffuse auroral arcs and bands indicate a predominant maximum at 100 km., while the aurorae with ray-structure have their most predominant maximum 6-10 km. higher.

During the winter 1930-31 experiments have been made with filter-photography of the aurorae. As the spectral lines in the auroral spectrum lie at a considerable distance from each other it is possible by using a suitable green-filter to isolate the green auroral line and thus get a photograph in the green monochromatic light of the aurora. Using a violet filter of suitable density it is possible to isolate the violet bands (4278 Å and 3914 Å) of the Nitrogen bandspectrum. Photographs of the aurorae taken simultaneously in green and violet show considerable differences with respect to the distribution of light. The results of a photometric investigation will be published later.

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THE ULTRA-VIOLET LIGHT THEORY OF AURORAE AND MAGNETIC STORMS.

By

E. O. Hulburt.

The ultraviolet light theory of aurorae and magnetic storms assumed that the sun, when active, emits a sudden (1/2 hour) blast or flare of ultraviolet light. For example, if 1/10000 of the solar surface suddenly glowed as a black body at 30000^{0}, the solar constant would be increased by 1 per cent and the ultraviolet energy, λ 500 to 1000A, by 10^{5}. This ultraviolet energy, completely absorbed in the high atmosphere, increases the ionization and the temperature of the high levels.

The calculated magnetic effects of the gravitational magnetic ion drift currents due to the increased ionization and of the dynamo currents due to the temperature changes were shown to agree with the observed variations in the earth's magnetic field during a magnetic storm. High flying neutral particles formed by collisions of the second kind, soar up to levels of 50000 km where they become ionized by the solar ultraviolet light. After being ionized they are constrained by the earth's magnetic field to fall into polar regions and cause aurorae.

The ultraviolet light theory suggested (1) that because of winds and the unusual production of ions the high atmosphere may be in violent agitation during the day of a magnetic storm, that it grows calmer at night and becomes agitated the next day if the storm continues, (2) that auroral displays in temperate latitudes should as a rule be accompanied by magnetic storms, and (3) that polar aurorae should follow several hours or a day after strong magnetic disturbances observed in temperate latitudes. These inferences were found to be in agreement with the data of wireless telegraphy, with the observations of magnetic observatories and with the observations of aurorae in temperate and polar latitudes.

The ultraviolet solar flare would be expected to cause changes in comets and therefore comet changes should be closely connected with terrestrial magnetic storms. The connection was found to be supported by the evidence from the behaviour of 31 comets scattered through the years 1848 to 1927. The positions of the comet, sun and earth at the epochs of the comet changes indicated that the solar flare was in a relatively wide angle.

It was found that the fluctuations in the zodiacal light and the gegenschein occurred during magnetic storms. This pointed the way to the development of an atmospheric ion theory of the zodiacal light and the gegenschein.

Phys. Rev. 36, 1560 (1930): 35, 1098 (1930): 34,344 (1929): 33, 1046 (1929): 33, 412 (1929): and references infra.

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ON THE RELATION OF MAGNETIC AGITATION TO SOLAR ACTIVITY.

By V. A. Kostitzin.

(Abstract*).

In this paper a short study is made of magnetic agitation in its relation to the frequency function of the solar spots. I show that besides the Wolfér's numbers the mean latitude and the dispersion of the spots are of importance. I am using principally the observations made at Parc St. Maur 1883-1900 and at Val Joyeux 1901-1924 and kindly transmitted to me by Professor Ch. Maurain, director of the Institut de Physique du Globe de l'Université de Paris. For the sake of verifying my results I am using also the observations of the Bombay Observatory (1883-1920) and of the Batavia Observatory (1902-1923).

1. The Criterion of magnetic disturbance. - All the existing criteria appear to me unsatisfactory. The character numbers are arbitrary, have little or no relation to the nature of the phenomenon, and record only the observer's very personal impression. I give several examples of surprising contradiction in the numerical estimate of the same magnetic disturbance by different observers. My proposal is to make systematic use of the notion (well known to mathematicians) of the total fluctuation of a function.

Let $W(t)$ be a real function. Let

$$t_0 < t_1 < \ldots < t_n < T$$

be a set of subdivisions of the interval (t_0, T). Then $\sum |W(t_k) - W(t_{k+1})|$ is called the fluctuation of W for this set of subdivisions. If the fluctuation has an upper bound $F^T_{t_0}$ independent of n for every choice of $t_1, t_2, \ldots, t_n$, $F^T_{t_0}$ is called the total fluctuation in the interval (t_0, T). If the function W has a set of consecutive maxima $t_1, t_3, \ldots$ and a set of consecutive minima $t_2, t_4, \ldots$, then

(1) the total fluctuation $= \Sigma |W(t_k) - W(t_{k+1})|$

(2) the positive fluctuation $= \Sigma \left[W(t_{2k+1}) - W(t_{2k})\right]$

(3) the negative fluctuation $= \Sigma \left[W(t_{2k-1}) - W(t_{2k})\right]$

If, for instance, W is the energy of the terrestrial magnetic field, the daily sum (2) will give the quantity of magnetic energy furnished to the Earth, the daily sum (3) the quantity of energy consumed, and the sum (1) the total fluctuation of the energy. This number can be chosen as a daily criterion of magnetic disturbance. The only difficulties that could arise are of a practical order. It is necessary to eliminate the microfluctuations, so that only the fluctuations

$$|W(t_k) - W(t_{k+1})| > \alpha$$

must be considered. Also the energy W cannot be registered

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* Annals de l'Institut de Physique du Globe de l'Université de Paris, t. VIII, 1930, p. 84-102.

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directly, and its calculation, even by the simple formula

$$(4) \qquad W = R^3 \left(H^2 + \frac{1}{4} Z^2\right),$$

may present great difficulties for observers. Yet I think that the last difficulty is not so great, and an experienced observer will be able to indicate the extrema of d on the magnetograms of H and Z. Besides it is possible to establish a set of standard magnetograms, and the observer will simply indicate the one that is the nearest to the present day's magnetogram, exactly as he now gives the numbers, 0, 1, 2 of the international classification. The days of great disturbance must be especially studied.

2. The yearly means - The eleven year period. There is a certain correspondence between the minima of solar activity and those of yearly means of magnetic agitation, but there is no correspondence between the maxima. While the solar activity has generally one maximum, in the 5th year of the solar cycle, the magnetic agitation has two - one in the 4th and another in the 7th year of the solar cycle, as shown in the following table: μ represents the mean latitude of the sunspots.

1	Mean sun-spot epoch in years.	0,5	1,5	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5
2	W-reduced Wolfer's number.	0,06	0,16	0,45	0,74	0,87	0,84	0,73	0,58	0,39	0,24	0,14
3	W calculated.	0,024	0,20	0,47	0,74	0,87	0,87	0,75	0,58	0,39	0,23	0,13
4	A-reduced magnetic agitation (great perturb.)	0,47	0,43	0,65	0,80	0,64	0,75	0,88	0,84	0,83	0,62	0,54
5	Sin μ obs.	0,385	0,347	0,326	0,270	0,225	0,214	0,185	0,174	0,151	0,139	0,116
6	h (dispersion) calc.	0,5	2,86	5,3	7,1	10,8	9,1	6,7	5,6	3,7	3,0	2,0

It appears from this table that the most magnetically perturbed are the post-maximal years of mean solar activity - 6th 7th and 8th. This conclusion is confirmed by the study of Bombay and Batavia observations.

3. Yearly variation of magnetic agitation. The yearly variation of magnetic agitation gives an indirect confirmation of this conclusion. In the beginning of a solar cycle the second half of a year appears more agitated than the first half. At the end of the solar cycle the first half of a year is more agitated than the second one. This means that the yearly variation is a superposition of two phenomena - of the yearly variation in the proper sense of the word and of the eleven-year cycle of magnetic agitation. I think this superposition can explain the spring or autumn displacement of maxima of magnetic agitation. Several authors attribute this phenomenon to climatic factors, but

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the Bombay (equator) and Batavia (south hemisphere, observations show that the displacements of the maxima are in the same sense as those in the northern hemisphere.

4. 27-day period. Though the existence of this period is contested by several authors, it has a real place in magnetic agitation according to the Paris observations, but not every year's observations permit it to be noted. It is remarkable that the great perturbations with this period are especially frequent in the last third of the solar cycle. In the same years there are very frequently groups of perturbed days.

5. Solar activity. First must be noticed the perceptible non-uniformity of the solar cycle. Generally the maximum of solar activity takes place in the first half of a cycle, but this rule has many exceptions, and in five out of fifteen cycles since 1755 the maximum is displaced to the second part of the cycle. It is interesting to mention that all five cycles belong to cycles of feeble solar activity.

The mean Wolfer's number and the mean latitude of the spots μ can be very well represented by the formulae

$$(5) \quad W = A\, k^2 t^3\, e^{-k^2 t^2}$$

$$(6) \quad \sin \mu = \frac{\sin \rho}{\sqrt{1+k^2 t^2}}$$

where $\sin \rho = 0.39$, $k^2 = 0{\cdot}08$

For a better characteristic of the solar activity it would be necessary to know the parameter of dispersion of spots about the mean latitude, but here the data are insufficient. This parameter is very small at the beginning of a cycle, then grows rapidly and reaches its maximum in the year before the maximum of solar activity, after which it decreases to zero at the end of the cycle.

Eliminating the time from the formulae (5) and (6) we find a relation between W and μ.

$$(7) \quad \begin{cases} W = B \left(\dfrac{\sin^2 \rho}{\sin^2 \mu} - 1 \right) e^{-2 \frac{\sin^2 \rho}{\sin^2 \mu}} & (\mu \leqslant \rho) \\ W = 0 & (\mu \geqslant \rho) \end{cases}$$

This empirical relation has the form of a statistical law. If desired the frequency function of spots could be deduced from it. In order to be able to reach even qualitative conclusions I assume that the frequency function has the form

$$(8) \quad \varphi(x) = C\, e^{-\frac{(z-x)^2}{h^2}} + C\, e^{-\frac{(z+x)^2}{h^2}}$$

where $x = R \tan \lambda$, $z = R \tan \mu$, λ is the latitude and C a parameter proportional to the Wolfer's number $W \sim 2\, C\, h \sqrt{\pi}$. The number of spots in the equatorial zone between latitudes $-\sigma$ and $+\sigma$ will be

$$(9) \quad \begin{cases} W_\sigma = \frac{1}{2} W \left[\Phi\left(\frac{\sigma+z}{h}\right) + \Phi\left(\frac{\sigma-z}{h}\right) \right] & (\sigma > z) \\ W_\sigma = \frac{1}{2} W \left[\Phi\left(\frac{\sigma+z}{h}\right) - \Phi\left(\frac{z-\sigma}{h}\right) \right] & (\sigma < z) \end{cases}$$

where Φ is the Gaussian integral.

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6. Relation between magnetic agitation and solar activity.

The existence of two maxima of magnetic agitation shows that there is no direct dependence upon the Wolfer number, and that the latitude of spots is more important. As the second (and chief) maximum of magnetic agitation falls at the end of the solar cycle when the number of spots is not great but they are near the equator, it is allowable to assume that the magnetically active spots or other connected phenomena influencing the earth's magnetism lie in the equatorial zone $(-\sigma\ ,\ +\sigma)$ and that the magnetic agitation A is proportional to the number of spots in this zone:

$$A = \sum W_{\sigma}.$$

This gives the equation

$$\frac{A}{W} = \frac{\Sigma}{2}\left[\phi\left(\frac{\sigma + z}{h}\right) + \phi\left(\frac{\sigma - z}{h}\right)\right] \qquad (\sigma > z)$$

$$\frac{A}{W} = \frac{\Sigma}{2}\left[\phi\left(\frac{\sigma + z}{h}\right) - \phi\left(\frac{z - \sigma}{h}\right)\right] \qquad (\sigma < z)$$

The functions A and W are known. We can determine the function h. Supposing $\Sigma = 60$, $\sigma = 0{,}117 = \tan 6^{\circ}40'$, and taking A and W from the table, I have calculated the function h, which appears to be qualitatively concordant with the observations. This simple example shows that the peculiarities of magnetic agitation can be explained by a very acceptable hypothesis concerning the frequency curve of spots, and by another hypothesis about the solar-equatorial origin of magnetic disturbances.

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COMPOSANTES PÉRIODIQUES DE L'ACTIVITÉ SOLAIRE ET COMPOSANTES CORRESPONDANTES DANS LE MAGNÉTISME TERRESTRE.

par M. et Mme H. Labrouste.

Abstract.

We have shown that there exists a close relationship between certain variations of terrestrial magnetism and solar activity. Regarding this, we find in the diurnal inequality of the declination various elementary waves presenting a striking similarity of curves with the corresponding elementary waves we have found to exist in solar activity. The same observation has been made concerning certain periods in the amplitude of the first term in the Fourier series, which term results from the harmonic analysis of the diurnal inequality. The influence of the solar activity is again made manifest in the range of annual and semi-annual variations of diurnal inequality. In sundry cases, we have been able to find numerical relationship existing between the elementary waves of both series of magnetic and solar phenomena.

It is desirable that analogous determinations, resulting from an international collaboration, should be effected in other stations concerning the above mentioned phenomena as well as the diurnal inequality of other magnetic elements.

On connaît les remarquables concordances trouvées entre l'activité solaire et la variation diurne de certains éléments magnétiques. On sait que, par des procédés convenables de calcul, par exemple en remplaçant chaque valeur mensuelle par une moyenne portant sur douze mois consécutifs, on arrive à éliminer les irrégularités accidentelles ainsi que la variation annuelle de l'amplitude diurne magnétique. On met ainsi en évidence un parallélisme étroit entre les deux séries de manifestations. Cependant, par ce traitement, on laisse de côté une partie des phénomènes: la comparaison porte principalement sur les plus grandes périodes parce que les petites (voisines de un an) disparaissent ou sont très réduites. Aussi nous sommes-nous proposé de compléter les précédentes études en tenant compte de ces petites composantes et en comparant entre elles les périodes correspondantes des deux phénomènes.

Les analyses de périodes ont été faites d'après les méthodes exposées dans un mémoire des Annales de l'Institut de Physique du Globe (I), auquel le lecteur est prié de se reporter. Les calculs ont été réalisés à l'aide de Tables numériques (2) qui fournissent directement, pour telle ou telle combinaison utilisée dans l'analyse, les valeurs du facteur d'amplitude relatif à chacune des composantes périodiques rencontrées et permettent d'isoler en vraie grandeur les différentes composantes élémentaires.

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(1) Analyse des graphiques résultant de la superposition de sinusoïdes, Ann. de l'Inst. de Phys. du Globe de Paris, t. VII, 1929. Voir aussi Comptes-Rendus de l'Académie des Sciences, T. 184. 1927.

(2) Tables numériques pour l'analyse des graphiques résultant de la superposition de sinusoïdes, 1930.

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Le travail résumé ici se rapporte à l'influence de l'activité solaire sur certains éléments périodiques de la variation diurne de la déclinaison.

I. Les données initiales utilisées dans ce qui suit sont d'une part les moyennes mensuelles des nombres de Wolf et Wolfer et d'autre part les moyennes mensuelles de l'amplitude diurne de la déclinaison dans le région parisienne (Observatoires du Parc St. Maur et du Val-Joyeux).

La recherche des composantes de l'activite solaire nous a permis d'isoler un certain nombre d'éléments périodiques (3). La plus petite période obtenue à partir des données mensuelles est d'environ 8 mois, tandis que l'etude des oscillations plus rapides, d'ailleurs commencée, exige l'utilisation de données moyennes portant sur des intervalles inférieurs à un mois.

Les composantes solaires rencontrées se classent de la manière suivante dans l'ordre des périodes décroissantes:

Une oscillation très lente, paraissant complexe mais non analysée faute de documents suffisamment anciens, dont les maxima tombent vers 1778 et 1847 et les minima vers 1813 et 1900.

Une composante de 22 ans 1/4 environ (période double de la période dite undécennale);

La composante undécennale;

Une composante de 5 ans 1/2 de période environ, harmonique de la précédente;

Une composante probablement complexe, de 37 mois en moyenne, dont la période n'est pas tout à fait constante;

Puis des composantes ayant des périodes respectives de 23 mois 1/2, de 17,6 mois, de 1 an et enfin de 8 mois.

Nous ne pouvons affirmer que les éléments périodiques donnés ci-dessus soient rigoureusement simples; en tous cas, la séparation déjà realisée à partir des données constitue une tentative qu'on pourra peut-être perfectionner.

Une analyse parallele de l'amplitude diurne de la déclinaison nous a permis de retrouver dans cette dernière la plupart des composantes signalées plus haut. L'amplitude diurne (D) a été choisie en prenant la différence entre la valeur maxima et la déclinaison vers 14 heures et sa valeur minima vers 8 heures sans tenir compte des journées fortement perturbées.

Pour les composantes de très grande période, la vérification n'a pu être faite à cause de l'absence de données suffisamment anciennes. En ravanche pour la composante de 22 ans 1/4 de période, on a pu mettre en évidence un fragment de courbe analogue à la courbe solaire dont le minimum (en 1904) coïncide avec celui de cette dernière.

Parmi les suivantes, la composante undécennale et celle de 5 ans 1/2 présentent un très bon accord pour toute la durée que nous possèdons, sous le rapport de la période, de la phase et de l'amplitude; tandis que, pour les composantes de plus grande fréquence, nous avons toujours retrouvé la même

(3) Comptes-Rendus de l'Assemblée de Stockholm (Août 1930) de l'Union Géodésique et Géophysique internationale, section de Magnétisme et Electricité terrestres.

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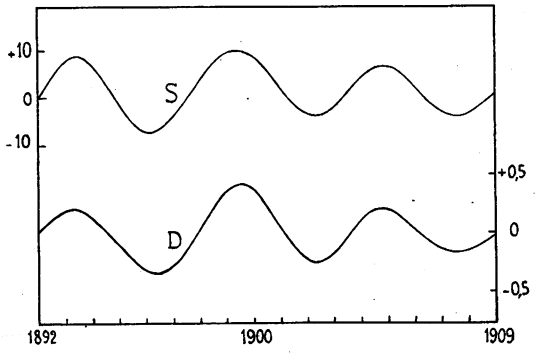
période, mais avons observé par endroits des désaccords en ce qui concerne la phase et l'amplitude.

Pour la courbe undécennale magnétique, qui est presque identique à la courbe solaire et peut lui être superposée par le choix d'une échelle convenable, on constate qu'à chaque unité des nombres de Wolf et Wolfer correspond une variation de 0¦041 (valeur moyenne entre 1883 et 1903). Nous avons trouvé une relation analogue dans le cas de la composante de 5 ans 1/2, avec le même nombre moyen de 0¦04 pour la variation magnétique correspondant à une unité de Wolf et Wolfer.

La figure reproduit un fragment de chacune des deux composantes solaire S et magnétique D pour cette période de 5 ans 1/2.



Période de 5 ans 1/2.

Il serait intéressant de rechercher une relation numérique analogue dans d'autres stations magnétiques du globe.

Parmi les périodes plus courtes, celles de 8 mois et de 17,6 mois ont montré les meilleures concordances de phase et d'amplitude. La composante de 8 mois reste en phase avec la composante solaire pendant toute la durée que nous avons étudiée (de 1902 à 1925).

Relativement aux amplitudes, toutes deux fournissent dans certaines régions la correspondance numérique déjà obtenue pour les grandes périodes tandis qu'en d'autres on observe certaines anomalies.

Les composantes de 37 mois et de 23 mois 1/2 présentent des divergences de phase plus marquées; on peut cependant dire qu'en moyenne la correspondance numérique des amplitudes subsiste à peu près, bien qu'il se présente des anomalies assez importantes dont la cause nous échappe actuellement.

II. L'amplitude diurne (D) de la déclinaison magnétique est une grandeur définie avec une certaine part d'arbitraire; le phénomène ne se présente pas chaque jour dans les mêmes conditions et on convient de rejeter ou de conserver les valeurs correspondantes de la variation suivant que la minimum et le maximum de la déclinaison tombent au voisinage ou loin de 8 heures et de 14 heures respectivement. Aussi nous a-t-il paru intéressant de faire des comparaisons analogues à celles qui précèdent sur

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des données magnétiques paraissant moins arbitraires. On peut utiliser par exemple les valeurs mensuelles moyennes de l'amplitude (C) de la composante diurne isolée de la composante semi-diurne ainsi que des autres harmoniques. Le premier terme de la série de Fourier, calculé à partir des moyennes horaires mensuelles de la déclinaison, nous a fourni les données de cette étude qui a été limitée aux petites périodes et à un intervalle de temps assez court (de 1901 à 1924).

D'une manière générale, la substitution de (C) à (D) améliore le parallélisme avec le phénomène solaire correspondant pour les composantes de 37 mois, 23 mois 1/2 et 17,6 mois sans cependant supprimer toutes les anomalies. Nos déterminations sont encore trop incomplètes pour donner une relation quantitative avec les nombres de Wolfer.

Une étude analogue est poursuivie sur la composante semi-diurne.

III. Dans ce qui précède, nous avons négligé complètement les périodes inférieures à 8 mois; pour leur étude, il faut envisager une analyse faisant appel aux valeurs quotidiennes. Ce travail a été commencé dans le cas de la période de 27 jours, qui a été mise en évidence parallèlement sur les nombres de Wolfer et sur l'amplitude diurne (D) de la déclinaison (I); nous avons également entrepris une analyse sur les valeurs horaires de la déclinaison dans le but d'étudier les composantes diurne et semi-diurne en relation avec l'activité solaire jour par jour.

IV. En dehors de l'action solaire mentionée ci-dessus, on en rencontre une autre. Nous avons signalé (2) qu'à la variation annuelle (A_1) de l'amplitude diurne (D) se superposent une composante semi-annuelle d'amplitude (A_2) assez importante et une composante quart-annuelle plus faible. Les courbes annuelle et semi-annuelle éprouvent au cours du temps des variations d'amplitude où l'on peut distinguer nettement un effet de l'activité solaire. On a trouvé, en utilisant les moyennes mensuelles de l'amplitude diurne (D) près de Paris, que l'amplitude double (A_1) varie entre 6' environ aux époques de minimum d'activité et sensiblement 8' aux époques de maximum; (A_2) varie de même entre 2' et 4' environ. Cette variation suit une marche parallèle à celle de l'activité solaire, ce qui a permis de déterminer une relation numérique entre la courbe des amplitudes (A_1) ou (A_2) et la courbe des nombres de Wolfer: à une unité Wolfer correspond pour chacune des deux composantes une variation de l'amplitude double d'environ 0;02 (3).

V. Les résultats précédents seraient à généraliser dans le cas des autres éléments magnétiques. L'ensemble des calculs à entreprendre dans ce domaine pour les étendre à un certain nombre de stations est si considérable qu'une collaboration internationale sur un programme d'études determiné paraît indispensable.

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(1) Comptes-Rendus de l'Académie des Sciences, t. 191, 1930.

(2) Comptes-Rendus de Stockholm (Août 1930) de l'Union Géodésique et Géophysique internationale, section de Magnétisme et Electricité terrestres.

(3) Sur la variation annuelle (et ses harmoniques) de l'amplitude diurne de la déclinaison; Communication faite au Congrès des Sociétés Savantes, 1931.

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ON THE AURORAL GREEN LINE.*

By

J. C. McLennan.

An extensive list of researches gives evidence of the lively interest that has been taken in the remarkable phenomenon of the Aurora Borealis. During the past ten years the spectrum of the Aurora Borealis has been intensively studied with the object of gaining information concerning the constitution and state of the upper atmosphere and concerning the agencies functioning in the occurrence of auroral displays. Recent investigations of the auroral spectrum have already thrown much light on problems that are of great importance in theoretical physics and promise to supply still more data of an illuminating nature.

It is now well known that the spectrum of the aurora is characterized by two outstanding features, the first of which is a set of bands with heads at or near λ = 3914 A.U. λ = 4278 A.U. λ = 4708 A.U. and λ 5227 A.U. The second is a narrow sharp line having a wavelength of approximately λ 5577 A.U. The bands have been shown by Lord Rayleigh[1], Slipher[2] and Vegard[3] to be identical with the so-called 'negative' bands obtained from singly ionised nitrogen molecules. Nitrogen in this state must therefore be one of the main constituents of that portion of the upper atmosphere in which auroral displays occur. As to the line λ = 5577 A.U., it is the strongest constituent of the spectrum of the aurora; moreover it has been recognized for some time that on moonless nights when no auroral displays are visible there may be observed in the spectrum of the light forming the background of the sky a faint yellow green spectral line which has been identified with this strong line λ = 5577 A.U. of the polar auroral spectrum. The single line radiation of this wavelength has been either observed or its spectrum photographed by Wiechert[4], Campbell[5], Slipher[6], Babcock[7], Rayleigh[8], McLennan[9], Vegard[10] and others. It has been found that this green line radiation is continuously emitted in all latitudes by all parts of the night sky not only when the latter is moonless and cloudless but also when it is moonlit and even when it is moderately over-clouded. It exists even in the absence of magnetic storms or auroral displays. The origin of the green auroral line has aroused much interest but it was not until the year 1925 that it was demonstrated that a line of exactly the same wavelength could be produced in the laboratory.

Vegard put forward the view that the auroral green line had its origin in the radiation from nitrogen that had a suitable molecular constitution, namely when the nitrogen was in a solid condition or in a vaporous state of low density and at low temperature and was bombarded with high speed electrons. This view was, however, definitely proven by a series of investigations to be unsatisfactory. Vegard[11] and also McLennan and Shrum[12] found that when they examined the light emitted by solid nitrogen that was bombarded by high speed electrons no radiation having the characteristics or the wavelength of the auroral green line was emitted. Instead they found in this region of the spectrum a band consisting of several components. The improbability of Vegard's assumption had been previously suggested by Atkinson, Grotrian and others and the spectroscopic evidence recorded showed definitely that it was incorrect.

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* The writer of this article desires to record here his indebtedness to his collaborator Mr. H. J. C. Ireton, M.A., for kind help in the preparation of it.

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Moreover, Babcock[13] had found in 1923 by making careful interferometer measurements that the wave-length of the green line of the night sky was λ 5577,35 $\pm$,005 A.U. and that the width of the line was not more than ,035 A.U.

In 1925 McLennan and Shrum[14] announced that they had been able to obtain a spectral line of wave-length λ = 5577 A.U. from the radiation produced by an electrical discharge in a tube containing a mixture of helium and oxygen. Its wave-length agreed well with the value of the wave-length of the green line of the night sky obtained by Babcock. Later they obtained the green line radiation with greater intensity in electrically excited mixtures of oxygen with neon or argon and still later they were able to produce it when an electrical discharge was passed through highly purified oxygen alone when the gas was at a low pressure. It was found, however, that when a rare gas, in particular argon, was mixed with the oxygen, the intensity of the oxygen green line was greatly increased. When an accurate determination of the wave-length of the oxygen green line was carried out by McLennan and McLeod[15], by the use of a Fabry and Perot étalon after the manner of Babcock, a remarkable agreement was found between the wave-length of the oxygen green line as measured by them and the value for the wave-length of the green line radiation of the night sky as measured by Babcock. The wave-length found by Babcock was λ = 5577,35 $\pm$,005 I.A.U. and the value obtained by McLennan and McLeod was λ = 5577,341 $\pm$,004 I.A.U. There would appear to be no doubt, therefore, that in the discovery by McLennan and Shrum of the production of the oxygen green line in excited oxygen atoms the origin of the auroral green line had been found. It follows therefore that oxygen as well as nitrogen must be present in the upper atmosphere in those regions where the auroral light is emitted.

Developments resulting from investigations in atomic structure made it possible in 1926 to predict from a study of the extra nuclear electronic configurations of any atom, the qualitative features of its spectrum. For neutral oxygen atoms theory predicted two singlet-triplet systems and one triplet-quintet system of spectral terms representing corresponding energy levels. Practically all the known lines of the atomic oxygen spectrum can be assigned to the triplet-quintet system. The scheme for the triplet-quintet system of atomic oxygen however provided no place for the radiation of wave-length λ = 5577 A.U. It follows, therefore, that this wave-length should belong to one or other of the two singlet-triplet term schemes given by the Heisenberg Hund Russell theory. As no wave-lengths in the spectrum of oxygen were known to belong to either of these two systems the problem of locating the energy levels involved in the production of the auroral green line radiation was an exceedingly difficult one. Considerations based on an analysis of the spectrum of the polar aurora and of that of the triplet-quintet system of oxygen made it clear that in the polar aurora we had a phenomenon that could be accounted for by an excitation potential of probably less than 20 volts. Moreover the absence from the spectrum of the non-polar aurora of all lines belonging to the triplet-quintet system of oxygen made it abundantly evident that in this phenomenon we had an excitation of probably less than 17 or 18 volts. Finally repeated and extensive laboratory experiments on the production of the green line radiation with mixtures of argon and oxygen shewed that strong green line radiation could be obtained in such experiments when it was demonstrable that the mean excitation potential available in the discharge tubes emitting the radiation was not greater than 13 or 14 volts. This indicated that the green line radiation must originate in an electronic transition between two of the three lowest energy levels in which it had

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been shewn that atoms of oxygen could exist. There were the ^1S_o, the $^1D_2$ and the $^3P_{o12}$ levels.

Prior to 1927 transitions involving any two of these levels accompanied by the emission of radiation would have been deemed 'forbidden' on account of a violation of the generally accepted so-called 'selection rules'. The evidence in support of such transitions, however, had become so strong that early in 1927 McLennan, Ruedy and McLeod were led to express the view that their occurrence was possible. The probability was that as the auroral green line was a singlet it was necessary to conclude that it originated in transitions of oxygen atoms from the ^1S_o state to the $^1D_2$ state.

The conclusion was also drawn by them that it was highly probable that 'forbidden' transitions between deep metastable states might be expected to occur quite generally.

Any doubt held or hesitancy felt in expressing this view vanished when Bowen[17] announced in the autumn of 1927 that he had discovered that eight of the stronger wave-lengths in the spectra of nebulae λ 7325, 6583, 6548.1, 5006.8, 4958.9, 4363.2, 3726.2 and 3728.9 A.U. could originate and doubtless did originate in transitions ordinarily classed as 'forbidden', from deep metastable states associated with the highly ionised atomic systems O_{II}, O_{III}, and N_{II}. Following this announcement efforts were specially directed to proving conclusively that the auroral green line originated in the manner indicated above.

One of the most satisfactory methods of identifying and classifying spectral lines is that based on an examination of the resolution experienced by the lines when the radiation giving rise to them is emitted by atoms in the presence of a magnetic field, or in other words on a study of the Zeeman Effect obtainable with the lines in question.

In an attempt to show definitely whether the auroral green line had its origin in transitions between the two low metastable states ^1S_o and $^1D_2$ or between one of them and the $^3P_{012}$ state McLennan McLeod and Ruedy[18] made an exact determination of the longitudinal Zeeman Effect, that is, observations were made along the direction of the magnetic field. The Zeeman pattern obtained was found to be a doublet with a separation equal to that of the outer components of a normal triplet. From an examination of the possible Zeeman resolutions resulting from transitions between metastable states and stable ones it was found that the only transitions that would give rise to a normal doublet pattern for longitudinal observations of the Zeeman Effect were those between ^1S_o and $^1D_2$ or between $^1D_2$ and ^3P_o. It was necessary therefore to decide which of these two transitions was the one that gave rise to the auroral green line. From Bowen's work it was seen that in nebular spectra lines exist that correspond to the transitions $^1D_2$ - $^3P_{12}$ but that lines corresponding to the transitions of the type $^1D_2$ - ^3P_o are either absent or are not separated sufficiently from the line corresponding to the transition $^1D_2$ - $^3P_1$ to be observed as a separate line. If we assume that the auroral green line arises from the transition $^1D_2$ - ^3P_o we should expect by analogy with nebular spectra that lines corresponding to the transitions $^1D_2$ - $^3P_1$ and $^1D_2$ - $^3P_2$ would accompany the green line and have greater intensity than it. As the wave number differences ^3P_o - $^3P_1$ and $^3P_1$ - $^3P_2$ for the lowest atomic levels of oxygen are 67 $cm.^{-1}$ and 158 $cm.^{-1}$ it follows that such spectral lines should be sufficiently separated to be detectable. Now as such lines did not appear in the auroral or the oxygen spectrum close to λ 5577 A.U. it was concluded that the green line could not be represented by the transition $^1D_2$ - ^3P_o but must be given by the

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other alternative, namely, the $^1S_0 - {}^1D_2$ transition. At the same time McLennan pointed out that from analogy with nebular spectra $^1D_2 - {}^3P_{012}$ transitions should exist. He also pointed out the possibility of the occurrence of the $^1S_0 - {}^3P_{012}$ transitions.

It will be recalled here, too, that McLennan in his Bakerian Lecture mentioned that in the course of his investigation of the spectral lines obtainable with oxygen-argon mixtures a strong sharp line having the wave-length λ 2977 A.U. was recorded on his plates when the oxygen auroral green line came out strongly. This line always came out single and was never accompanied by a second line with a wave-number difference of 67 cm.$^{-1}$ or 158 cm.$^{-1}$ ($^3P_{02} - {}^3P_1$). Further, no wave-lengths appeared on his plates at or near λ 6363.8 though it was thought they should have been there as λ 2977 A.U. corresponded to one of the transitions $^1S_0 - {}^3P_{012}$. A careful search was made for them by McLennan and his co-workers but they were never found. There the matter rested for a time. Recently a way for clearing the matter up was found by Frerichs[19] who developed methods for the powerful excitation of the oxygen arc spectrum and he was therefore able to observe many new lines in its spectrum. When he classified these lines together with those already known he was able to calculate the numerical values of the energy levels for atoms of oxygen in the $^1S_0$ and the $^1D_2$ states. This enabled him to calculate the frequency difference for the $^1S_0 - {}^1D_2$ transition and this frequency was found to be identical with that for the auroral green line. The classification suggested by McLennan was therefore definitely and finally confirmed. Frerichs' analysis of the term scheme for atomic oxygen also enabled him to predict with definiteness the frequencies of the spectral lines corresponding to the transitions $^1S_0 - {}^3P_{012}$ and $^1D_2 - {}^3P_{012}$. Frerichs states that he looked for spectral lines with the frequencies which his term values for $^1D_2$ and $^3P_{012}$ gave him but that like the writer he did not succeed in finding them. They were found by Paschen[20], however, in July last on some plates of the oxygen spectrum taken by Hopfield in Paschen's Laboratory under exceptionally high and heavy excitation. The lines had the wave-lengths λ 6300.03, 6364.02 and 6391.0 A.U. and were exactly the ones demanded by the known values of the energy levels $^3P_{012}$ of the oxygen atom and the energy level $^1D_2$ found for it by Frerichs. In that connection it is of interest to note that McLennan and Welch in a recent investigation found the line originally observed by McLennan at λ 2977 A.U. to have with refined measurement the wave-length λ 2973 A.U. This line would then appear from Frerichs' values of the energy levels to be the one having its frequency given by $^1S_0 - {}^3P_1$. Lines with the frequencies $^1S_0 - {}^3P_1$ and $^1S_0 - {}^3P_2$ have not as yet been observed.

In dealing with this subject it should perhaps be pointed out that Hopfield[28] has called attention to the fact that the oxygen lines λ 6300 and 6364 A.U. appear in nebular spectra and are the only 'nebulium lines' that have as yet been reproduced in laboratory experiments. An oxygen line at λ 6374.392 A.U. that is as yet unclassified, and that appeared strongly on his plates Hopfield considers to be the hitherto unidentified coronal line λ 6374 A.U. It is also of interest to note that L. A. Sommer[21] claims to have found in the spectrum of the light of the night sky the wave-lengths λ 6300 and 6363 A.U. and that Vegard[22] and others have frequently reported observing a line at λ 6320 A.U. in the spectrum of the polar aurora. No radiation of the wave-length of those found by Sommer, however, appears to have been recorded hitherto in spectrograms of the light of the night sky.

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A further study of the auroral green line radiation has led recently to some interesting and definite conclusions of first importance in theoretical physics. The questions referred to earlier for the replacement of the absolute prohibition of 'selection rules' by a low transition probability left unexplained the contradiction of the selection principles for ordinary or so-called dipole radiation. In the case of forbidden lines the moment of the atom giving rise to dipole radiation is absent but a higher moment of the atom, the so-called quadrupole moment, is present to an observable extent. Rubinowicz[22]. from theoretical considerations of the new quantum mechanics shewed that a difference in the Zeeman pattern should exist for dipole and quadrupole radiation. In the case of the auroral green line he showed that for longitudinal observations the Zeeman pattern should consist of a normal doublet for both dipole and quadrupole radiation. For transverse observations of the Zeeman Effect, however, the pattern should consist of a normal triplet in the case of dipole radiation and a quartet in the case of quadrupole radiation. It follows therefore that transverse observations on the Zeeman Effect with the oxygen green line should furnish a critical test for Rubinowicz's theory of quadrupole radiation. An experimental test of this theory was made by Frerichs and Campbell[23]. Observations of the transverse Zeeman Effect of the oxygen green line were made with a Fabry and Perot interferometer and their results completely confirmed the theory put forward. McLennan and Welsh in some experiments on the oxygen green line to be published shortly have also found that the pattern obtained with the transverse Zeeman Effect is similar to that recorded by Frerichs and Campbell. In their experiments a thirty plate Echelon was used in combination with a spectrograph of high light power.

In attempts to obtain information from another direction as to the origin of the excitation of the auroral green line and the physical state of the upper atmosphere experiments have been made to determine whether the intensity of the green line radiation of the night sky varies with the time and place of observation.

Lord Rayleigh[24]. from a survey organised by him and carried out with the co-operation of observers at various stations throughout the world obtained some definite results on the variation of the intensity of the auroral green line radiation from the night sky. The results obtained indicate an annual periodicity with a maximum intensity in October in the northern hemisphere and in April in the southern hemisphere. He also found indications of a progressive increase in the intensity of the green line from year to year over a period of four years. From observations made in England alone Lord Rayleigh found a regular diurnal variation in the intensity of the green line radiation with a maximum at midnight. In these latter experiments he used a photo-electric cell to record the intensity of the light.

In a series of experiments carried out independently and practically concurrently with those of Lord Rayleigh, McLennan[25]. and his associates found that there appeared to be from evening twilight onwards a gradual increase in the intensity of the auroral green light received from the zenith of a clear moonless night sky. Their observations showed that the intensity reached a maximum at about an hour and a half after midnight and that from that time onwards until morning twilight it gradually lessened. Series of observations were made at two stations widely separated, namely at Flagstaff, Arizona, United States of America, and near Toronto, Canada. Two methods of making the observations were followed. In the one case a continuous record of the intensity was obtained by means of a filter, and a slit that moved at a continuous rate over a photographic plate. In the other a sequence of records of the intensity of the green line radiation was obtained from a series of successive spectrograms of short exposure taken with one

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or other of a number of specially designed spectrographs of very high light power.

In order to obtain still more information on aurorae and on the conditions in the upper atmosphere responsible for their occurrence Størmer and his co-workers have carried out an extensive series of researches in Norway on a determination of the position in space of the aurora. The method used was a photographic one. The principle on which this method is founded is a simple one. The same auroral display was photographed simultaneously from two stations a known distance apart and connected by telephone. The parallax of any point which could be identified on the two plates was measured from the different positions of this point on the two plates relative to the stars. From the results obtained in a series of observations described in the Geofysiske Publicationer Vol.1, numbers 1, 4 and 5, and Vol.4, number 7, Størmer has calculated the heights of the upper and lower edges of many auroral displays. Their results show that very few displays occur below 80 km. and that above this level the number increases rapidly with the most frequent occurrences beginning at a height of 106 km. Above this height the number of aurorae fall rapidly although some have been observed as high as 500 km. and 750 km.

It is important that researches analogous to those made in Norway should be conducted in other countries. A series of stations of this type would give important information on the occurrence of different forms of aurorae, on their position in space and on the extent of the luminous arcs that appear in the displays. With this object in view McLennan recently instituted some preliminary investigations of this nature in Northern Ontario, Canada, and observations were made during January 1931 at a latitude of about 50 degrees. Simultaneous photographs of aurora were taken at two stations, Blacksmith Rapids and Coral Rapids on the Abitibbi River near James Bay. The results of these observations will be published shortly. Preliminary calculations made from a series of the photographs taken indicate that the height of the lower edges varied from 75 to 150 km. The variation in the form of the aurora was very clearly shown on different photographs which will be reproduced.

In order to gain additional definite information about the constitution of the upper atmosphere suggestions for future experiments have been brought forward by Chapman, Størmer, Vegard and others.

It has been suggested that there should be still further studies made of aurorae, of the behaviour of meteors, of the light of the night sky, of the luminous night clouds and of the zodiacal light. The two phenomena which might be expected to give the most valuable information are the aurora borealis and the light of the night sky, since they occur in higher strata of the atmosphere. Results obtained from a study of these should be combined with facts obtained from other sources and from experiments carried out in the laboratory.

It is important that researches analogous to those made in Norway should be made in other countries. If a series of stations could be established round the northern hemisphere and simultaneous observations made from all these stations important information might be gained that would enable one to pick out the correct theory of the origin of aurorae from a number now being brought forward. Accurate determinations of the upper and lower limits of the arcs, rays, and luminous draperies with the widths of the latter would be especially interesting. Analogous observations should be made for the southern lights in the Antarctic and in places in the southern hemisphere where aurorae are visible.

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It is desirable that there should be made simultaneous and continuous observations of solar activity, earth currents and auroral displays during magnetic storms. In these cases the times of occurrence should be very accurately recorded so as to permit the correlation of the concurrent phenomena.

It would be desirable to make observations of the potential gradient and the conductivity of the air during an auroral display. Since the aurora is electrical in its nature it might have some detectable action on those phenomena. A connection between the aurora and the properties of the conducting layer might be investigated by measuring at the same place the height of an aurora simultaneously with radio measurements of the height of the conducting layer. It might, too, be possible to establish a connection between aurora and the penetrating radiation entering the earth's atmosphere from space.

It is of the greatest importance to obtain the wavelengths of the lines in the auroral spectrum as accurately as possible together with a study of the structure and relative intensity of the lines. For this purpose photographs of the spectrum of the light from different portions of auroral display should be taken with instruments of high dispersion and high light power. In connection with the photography of aurorae simultaneously from two or more stations photographs of the auroral displays should be taken with light filters in order to find out if possible the distribution of the gases nitrogen and oxygen at different levels. Studies such as those indicated above should be made of the aurora at various latitudes and at various distances north and south of the auroral zone of maximum frequency. Such experiments should be carried on over a series of years both in arctic and the antarctic zones. In view of Sommer's success in obtaining spectrograms of the light of the night sky shewing the wave-lengths λ 6300 and 6363 A.U. it would be profitable to study the intensity of these lines when obtained at various times during the night and when obtained with light from different parts of the moonless night sky. Here again it would be essential to have spectrographs of very high light power. This involves the development of suitable rapid camera lenses having, if possible, only a single component. Some progress in this direction has already been described by McLennan[26] and Ireton. With such spectrographs one can record the spectrum of the radiation of the night sky in a very short time. It is thus possible for example to follow the variation of the intensity of the light of the night sky by an examination of the intensities of the lines of spectra recorded with short exposures and taken consecutively throughout the night. From careful measurements by interferometry methods of the half width of the oxygen green line produced under controlled conditions in the laboratory it should be possible by comparing the results with Babcock's value for the green line of the night sky radiation to arrive at some definite conclusions about the temperature of that portion of the upper atmosphere in which the non-polar green line radiation originates. It would be helpful too if measurements were made with bolometers or photo-electric cells of the luminosity of given defined portions of the night sky. From these results some estimate might be obtained of the average number of atomic transitions in a column of the atmosphere a square metre in cross section that contribute each second to the production of the green line radiation.

Lord Rayleigh[27], who is the only one that, up to the present, has investigated this point, finds that 1.81×10^{12} atomic transitions per second from each square metre will account for the green line radiation coming to us from the night sky.

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Since the ozone content of the upper atmosphere at any time may have a definite relation to the number of oxygen atoms in the atmosphere at the same time in the $^1S_0$ state, it is of importance that as much information as possible should be obtained about variations that occur in the amount and distribution of the ozone in the upper atmosphere. It is of importance too to measure in the laboratory more accurately the coefficient of absorption of ozone for radiations in various regions of the spectrum. The question of the absorption of various wavelengths by ozone is intimately connected with its photochemistry. Moreover the details of the processes by which ozone is produced from oxygen and by which ozone reverts to oxygen are not as yet fully known and should be more fully investigated. We have no adequate information at present on this fundamental problem. Finally determinations of the average range of the daily variations of the amount of ozone in the atmosphere should be made. Measurements of the seasonal variation of ozone in high latitudes are also of importance.

It would be particularly interesting if information could be obtained on the intensity of the auroral green line radiation from the sky in polar regions during the long winter night and in the absence of polar auroral displays. If the ozone content of the upper atmosphere could be measured or estimated at intervals during the same period at the same observing station or stations one could see if the green line radiation of the non-polar aurora was related in any way to the ozone content of the atmosphere.

In conclusion I may be permitted to point to the desirability of studying at stations other than and in addition to those in Norway the interesting long-interval radio-wave echo phenomenon observed in recent years and described by Störmer. Would the conditions that obtain when polar auroral displays are the most brilliant be the ones most favourable or not for obtaining these puzzling echoes of radio waves?

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March 15th, 1931.

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AURORAL PHENOMENA AND THE SOLAR CHROMOSPHERE.

by Donald H. Menzel.

It is well known that the aurora polaris and certain types of magnetic disturbances are to be ascribed to solar activity. Two suggestions regarding the nature of this relationship have been made. One theory supposes that a small fraction, perhaps 10^{-4}, of the solar surface may occasionally flash out with a temperature of 30,000°, the remainder being at 6000°. These super-heated areas would scarcely affect the solar constant, but they would give rise to an excess of energy in the extreme ultra-violet. The 'blasts' of ultra-violet energy from these hot spots would, on reaching the earth's atmosphere, cause photoelectric ionization, which in turn would excite the luminosity of the aurora. The second suggestion is that great clouds of ions and electrons, shot from the sun, may strike the earth and produce the observed disturbances. Observations of the chromosphere, therefore, may have some bearing on the problem, for, in the one case, chromospheric excitation would be affected by the ultra-violet flux, while, in the other, emission of atoms, as the existence of prominences attests, is also a chromospheric phenomenon.

Study of spectrograms of the solar chromosphere (flash spectra), taken by Dr. W. W. Campbell upon Lick Observatory eclipse expeditions in 1898, 1900, 1905 and 1908, yielded some results that, at first, seemed to be entirely inexplicable. The full report of the investigation of these spectrograms is contained in Publications of the Lick Observatory, Volume 17, (in press). Perhaps the most outstanding feature of the chromosphere, as far as excitation is concerned, is the occurrence of the helium lines, λ 4686 of ionized helium in particular. It is easily computed that the ratio of N_{He^+}, the number of ionized 3-quantum helium atoms per cm^3 to N_{He}, the number of neutral 1-quantum helium atoms per cm^3, is given by the relation

$$\log \frac{N_{He^+}}{N_{He}} = \frac{-5048\ (I + E)}{T} + 2.5 \log T - 6.5 - \log P,$$

where I and E are the ionization and excitation potentials, T is the absolute temperature and P the electron pressure. For the line λ 4686, $I + E = 72.6$ volts. P is of the order 10^{-8} atmospheres. Judging from the probable abundance of helium and from the intensity of the λ 4686 line, we conclude that

$$\frac{N_{He^+}}{N_{He}} \sim 10^{-8},$$

though the estimate may be in error by a factor fully as great as 10^3. The calculation leads to a temperature of 18,000°. Fortunately this result is very insensitive to possible errors in the estimated ratio. A factor of 10^5 would produce a change of only several thousand degrees in the computed temperature.

The increase in intensity of the helium lines (including λ 4686) in prominences suggests that the photospheric areas underlying the eruptions are at temperatures even higher than 28,000°. It is natural to infer that the prominence is caused by the hot spot, though it is uncertain whether radiation-pressure contributes much to the motions of the gases, since there appears to be no tendency for the various materials to separate out. We should scarcely expect to find atoms of all varieties experiencing equal accelerations.

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Analysis of the plates has led to the view that the solar chromosphere is not quiescent. The 'spikes' or 'flames' that form the chromosphere are probably rooted in the 'faculae', the brighter areas of the granulated network that covers the solar disk. Further, it seems probable that the difference between a chromospheric 'spike' and a prominence is merely one of magnitude and not of kind. Such a view of chromospheric constitution appears to be in accord with the characteristics of the flash spectrum, including the observation that the mean-square velocities of the atoms of the gas apparently increase with height. It provides a possible explanation of the marked differences between spectroheliograms taken in calcium light and those taken in hydrogen light. Most of the calcium in the solar atmosphere is singly ionized and, since H and K are ultimate lines requiring no special excitation to produce them, there will be an abundance of ionized calcium atoms over the entire solar surface. Hydrogen, on the other hand, is mainly neutral and requires very high excitation (10 volts) before the lines of the Balmer series can be absorbed at all. Hence the number of 2-quantum atoms will be greatly increased over the faculae and the hydrogen spectroheliograms will reproduce the granular arrangement of the faculae. The non-appearance of the helium lines in absorption is also explained by this view. The atom requires so high excitation (20 volts) that the percentage of excited atoms in the reversing layer will be very small. They show in emission because the chromosphere is a 'hot spot' phenomenon. Nicholson reports that the D_3 line often appears in absorption over an area several minutes of arc in radius around a group of spots. He has further expressed the opinion (in correspondence) that at sun-spot maximum it could probably be detected as a faint absorption line in integrated sunlight, if high dispersion and photographic plates of great contrast were to be employed in the observations. This is all in accord with the foregoing chromospheric theory.

In conclusion, it may be stated that spectrograms of the chromosphere, indicating as they do an excess of ultra-violet energy from high temperature faculae, furnish observational support for the assumption made in developing one of the auroral theories previously referred to. It is tempting to suggest that the variation in intensity of the ultra-violet radiation, as discovered by Pettit, may be closely related to changes in the activity of the superheated areas. If either of the above auroral theories is correct, we should expect to find a closer correlation between prominences and aurorae than between sun-spots and aurorae. Unfortunately, observational data relating to the occurrence of prominences are too meager to decide this important question. If the theory of the chromosphere, here outlined, is correct, we should not speak of the sun-spots as causing auroral disturbances. More accurately, we should say that sun-spots, high temperature faculae, prominences, aurorae, and magnetic storms are all due to some fundamental activity of the sun, the precise nature of which is still undetermined.

QUANTITATIVE DETERMINATION OF PHYSICAL CONDITIONS EXISTING IN SUN-SPOTS.

by Charlotte E. Moore.

A determination of the temperature, pressure and amount of material above sun-spots has resulted from a detailed study of the atomic lines in the sun-spot spectrum.

Intensities have been estimated on the Rowland scale for about 6000 lines of atomic origin in the spot spectrum, from original negatives and prints made from them. The plates were

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taken with the 150-foot tower telescope and 75-foot spectrograph on Mount Wilson, for the splendid map of the spot spectrum. The third order was used from λ3900 to λ5400 and the second order from λ5400 to λ6000. The spectrum of the disk appears on each side of the spot spectrum. The use of a quarter-wave plate and Nicol prism gives the lines subject to Zeeman effect a zigzag appearance in the latter; this makes it possible to select the atomic lines. On comparing the intensities estimated from the prints with those from the plates no systematic difference was found.

The identifications of lines in the solar spectrum from λ2975 to λ6635 and in the spot from λ3894 to λ6635 have been revised and extended. Lines of Lu^+ have been identified for the first time. The principal criteria employed have been laboratory wavelengths and intensities, the multiplet relations and excitation potentials (which are now available for almost all elements except the rare-earths) and the behaviour of lines in the spectrum of γ Cygni, a giant star of class F8. Six hundred and fifty-one faint solar lines not previously identified have been recognized as faint members of multiplets, not yet observed in the laboratory, but accurately predictable. Of these 425 are due to Fe, 41 to Fe^+, 88 to Ni, 54 to Cr^+ and 43 to Ti^+. Three hundred and ninety-four new atomic lines which appear only in the spot spectrum have been measured and 186 identified.

A quantitative study of the composition of the atmosphere above the spots has been based on the calibration of the Rowland intensity scale. This gives a quantity Y which is the logarithm of the ratio of the number of atoms producing a line in the spot spectrum to that effective in the formation of the same line in the solar spectrum. From thermodynamic theory $Y = Y_0 + S E_\chi$, where Y_0 is the logarithm of the ratio of the numbers of neutral atoms above equal areas of the photospheres of spot and disk, E_χ is the excitation potential and $S = 5040\ (1/T - 1/T')$. T and T' are the effective temperatures of disk and spot respectively. For enhanced lines Y_0 must be replaced by Y_1, the corresponding quantity for ionized atoms. The observed data from 6 elements give a weighted mean value of S equal to $- 0.190 \pm 0.010$. Taking $T = 5740°K$, $T' = 4720° \pm 40K$, where the probable error is a measure of the accordance of the observations. From the observed values of Y_0 and Y_1 and the Saha equation as modified by Pannekoek and Fowler, the ratio of the electron pressures P_e' (spot) and P_e (disk) can be found. Seven elements have a sufficient number of arc and spark lines present in the solar and spot spectra to be used. The weighted mean value of $\log P_e'/P_e$ is $- 0.22 \pm 0.07$; i.e. the ratio of the electron pressure to that over the disk is 0.60 ± 0.10.

Russell has defined the 'level of ionization' as the ionization potential of an atom which would be just 50 per cent ionized under given conditions. For the spot this level is 7.0 ± 0.1 volts as compared with 8.5 ± 0.1 for the disk. From these quantities the percentages of ionization of disk and spot were calculated for 28 elements. Comparing these percentages with Y_0 and Y_1 it was found that the amount of material per unit area above the spot is greater than that above the disk. The ratio of these amounts, C, was determined for 19 elements in the neutral state and 11 in the ionized state, giving $\log C = \pm 0.23 + 0.03$ or $C = 1.70 \pm 0.11$.

Checks upon these results can be obtained in two ways. First, the mean percentage of ionization was computed for both disk and spot from Russell's data for the composition of the solar atmosphere; and hence the ratio of the number of ions per square centimeter above the two. This should equal the ratio of electron pressures. The calculated value of $\log P_e'/P_e$ is $- 0.17$ as against -0.22 observed. Second, from Gaunt's relation that the absorption coefficient K varies as $P_e T^{-3/2}$ it is possible to calculate the increased transparency above the spot and to determine both C and P_e'/P_e theoretically when T' is given. With $T' = 4720°$, $\log C = +0.13$ and

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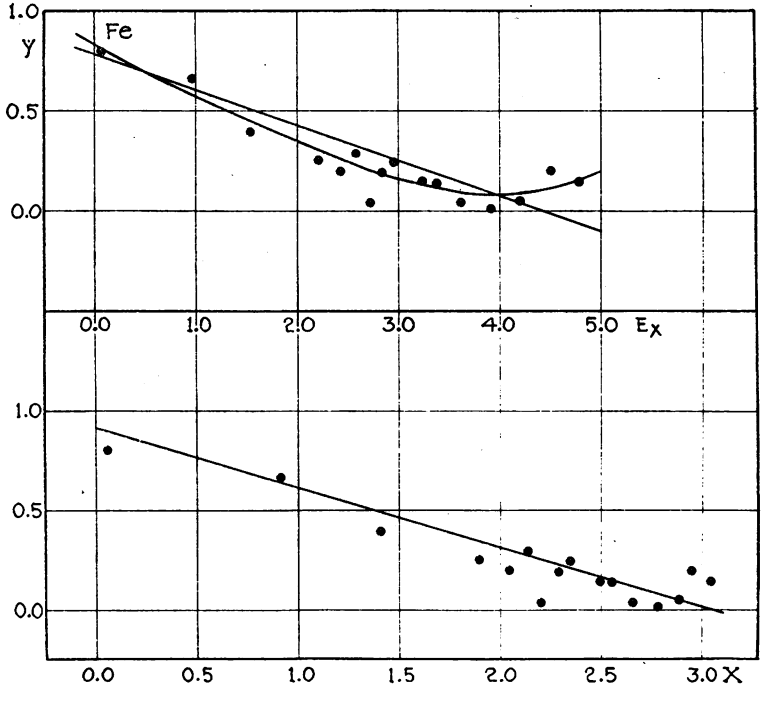
log P_e'/P_e = - 0.26. The agreement with observation is satisfactory considering the approximate nature of the theory.

Adams and Russell introduced an empirical correction to care for a supposed departure from thermodynamic equilibrium when they determined the temperatures of the stars by the method used here. If applied to the spot spectrum this correction gives T' = 4290°, log P_e/P_e = - 1.09 and log C = + 0.31. The first theoretical check gives log P_e'/P_e = - 0.11 and the second gives log P_e'/P_e = -0.38 and log C = + 0.19. The plots of the Fe data without and with this empirical correction are given in the Figure. The upper plot, which is that of Y against E_χ shows an unexplained curvature similar to that obtained in the case of the stars. Below is a plot of Y against X, where X = 1.05 E_χ - 0.087 E_χ^2. The curvature is removed, but the great discordance in log P_e'/P_e indicates decisively that no such empirical correction is applicable in the case of the sun-spot spectrum.

From the three constants T', P_e'/P_e and C derived from observation, the intensities of the atomic lines in the spot spectrum can be calculated for all lines of known energy relations. These calculations have been made for a number of the most difficult cases in the whole spectrum; lines of H, O, Si, Si^+, Mg and Mg^+. The average discordance of observed and calculated spot intensities is ± 1 unit of the Rowland scale, excluding a few lines so strong that estimates are meaningless. Similar calculations made for all lines in a selected region in the red show good agreement between observed and calculated values except for certain lines due to Ti, V, and Zv, which are very faint in the spectrum of the disk. Further study of such cases is desirable. Apart from this difficulty the intensities of lines in the sun-spot spectrum have been quantitatively explained by physical and thermodynamic theory.



Slopes for Fe without and with empirical correction.

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SOLAR CHARACTER-FIGURES.

By Seth B. Nicholson.

In cooperation with several other observatories estimates of the solar activity have been made at the Mount Wilson Observatory since the beginning of 1928. The daily estimates which have been contributed from Mount Wilson refer to the bright flocculi of calcium, the bright flocculi of hydrogen, and the dark flocculi of hydrogen, each expressed as character-figures on a scale of 5. In order to keep the scale as uniform as possible, standard spectroheliograms have been selected to which reference is made when the character-figures are assigned. These standard scale plates have proved so convenient and so useful in maintaining a uniform scale, especially when the estimates are made by more than one observer, that the adoption of some such system is recommended for each observatory unless an equivalent has already been adopted.

When comparisons of solar activity are to be made with terrestrial phenomena for the purpose of determining what correlations exist and whether such correlations are fundamental or accidental, as long a series of observations as possible is essential. Spectroheliograms are available at several observatories for many years back so that it is possible to extend the estimates of character-figures backward for at least two sun-spot cycles if desired. Character-figures have been estimated at Mount Wilson for each spectroheliogram back to the beginning of 1923, which includes the last spot minimum. These and still earlier data will appear soon in the proposed new Solar Bulletins to be issued from Zurich for the years prior to 1928. A preliminary survey of this material reveals no striking deviations from the data for sun-spots and prominences already published.

In relation to terrestrial magnetism the results emphasize the importance of localized solar activity of abnormal intensity and indicate that the records of such phenomena are perhaps the most important contribution to the Bulletins. It may even be desirable to establish a new character figure based on the intensity rather than the area of bright hydrogen flocculi.

THE TEMPERATURE OF SUN-SPOTS FROM RADIATION MEASUREMENTS.

By Edison Pettit and Seth B. Nicholson.

The temperature of sun-spots was derived (1) from the spectral energy-curve, (2) from total radiation and (3) from water-cell transmissions.

In the first method a glass monochrometor set up in the 150 foot tower-telescope was provided with a vacuum thermocouple and photographic registering device. With this equipment energy-curves were obtained on the umbra of the spot and on the neighboring photosphere between λ 0.4 μ and λ 2.2 μ. From these curves the ratio of the energy in the spot to that in the photosphere for any wave-length between λ 0.4 μ and λ 2.2 μ could be found. The values of this ratio for wave-lengths between 0.3 μ and 0.4 μ were determined by photographic photometry with a 1-meter concavegrating spectrograph and all-speculum telescope. When the energy-ratio, spot to photosphere, is plotted against wave-length it is found that it varies in a nearly linear fashion from 0.21 at λ 0.3 μ to 0.80 at λ 1.7 μ after which it is nearly constant. Depressions at λ 1.38 μ and λ 1.9 μ are believed to be errors due to the atmospheric absorption bands at these points.

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The energy-curve of the spot was obtained (1) by multiplying Abbot's spectral energy-curve for the center of the disk by the ratio, spot to photosphere, for each wave-length and (2) by multiplying the black-body curve for 5955° K by these ratios. The resultant spectral energy-curve for the spot is not a black-body curve in either case, but more nearly so in the latter. The resulting temperature of a black body of equal total energy for the two cases is 4860° K and 4750° K respectively.

The ratio of the total energy in the spot to that in the photosphere was measured directly with the thermocouple and found to be 0.47. When corrected for instrumental and atmospheric absorptions it becomes 0.44 which corresponds to a temperature of 4850° K. The radiation of the spot is found to fall gradually from the photosphere to the umbra without indications of increase such as Secchi obtained.

The water-cell transmission of radiation from the umbra of a spot was found to be 0.47 magnitudes while the photosphere at the center of the disk gave 0.38 magnitudes. Since the water-cell absorptions for integrated sunlight is 0.03 magnitudes greater than for the center of the disk this makes the value for sunspots in average position on the disk 0.50 magnitudes, corresponding to spectral classification dG7 and temperature 4720° K. This inference is derived from our work on stellar radiation.

The scattered photospheric light measured at the limb of the sun appears to be even more than sufficient to explain the discrepancy between the spectral energy-curves of the sunspot and that of a black body of equal total energy.

The proper temperature to be assigned to the photosphere from measures of the solar constant is obtained from the following argument. We found the rate of radiation at the center of the disk to be 16 per cent greater than that of integrated solar radiation, which makes the rate at this point 2.25 cal.cm^{-2} min^{-1} and the corresponding temperature from the fourth power law 5955° K.

We finally have the following temperature data:

Temperature of the photosphere at the center of the disk	5955° K
Temperature of sun-spot umbra from spectral distribution of energy using Abbot's spectral energy-curve for center of the disk	4860° K
Temperature of sun-spot umbra from spectral distribution of energy using black-body curve at 5955° K for center of the disk	4750° K
Temperature of sun-spot umbra from total radiation	4850° K
Temperature of sun-spot umbra from water-cell absorptions	4720° K

From these data it appears that the temperature of the umbra of a sun-spot is probably near 4800° K or possibly a little less.

Carnegie Institution of Washington,
Mount Wilson Observatory,
February, 1931.

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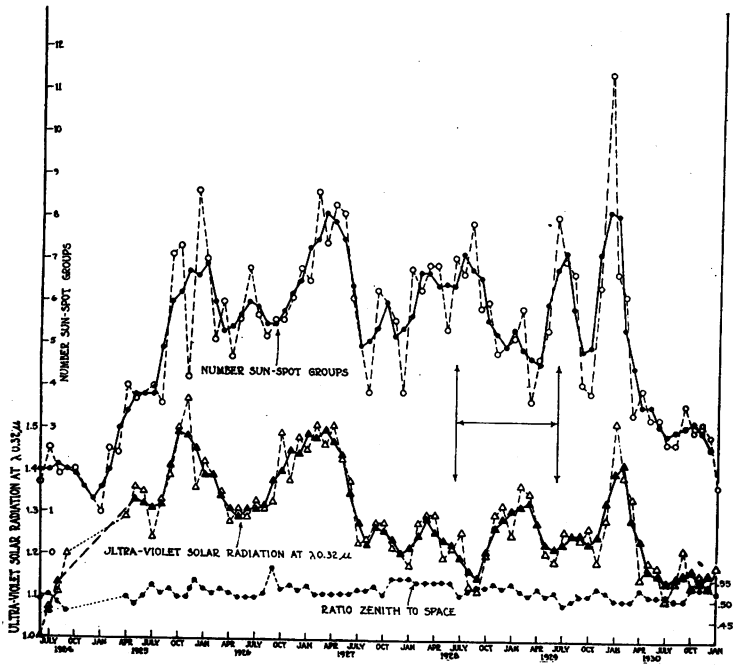
ULTRA-VIOLET SOLAR RADIATION DURING THE PERIOD 1924-1931.

By Edison Pettit.

Measurements of the ratio ultra-violet light at λ 0.32 μ to green light at λ 0.5 μ in the sun were continued as in previous years with the same apparatus. Briefly it consists of a thermo-electric comparison of the intensity of sunlight transmitted by silver with that transmitted by gold made automatically throughout the morning hours of clear days on Mount Wilson. A complete comparison is made each four minutes, the galvanometer deflections being registered photographically. After measurement of the plates the logarithms of the ratios of the galvanometer deflections are plotted against secant Z and the resulting straight-line plot projected to no atmosphere which gives a characteristic figure for each day. The arbitrary unit employed is the average value for the first month of observing, June, 1924.

The monthly averages (open triangles) and three-month running means (black triangles) of the measures of ultra-violet solar radiation are plotted in the figure together with the similar values of the number of sun-spot groups observed daily.

A kind of general correspondence seems to exist between the two curves smoothed by three-month running averages except for the year, June 1928-June 1929 approximately, as is indicated by the arrows in the figure. No instrumental reason for this has so far appeared although it has been searched for.



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The highest values in the monthly mean of the measures of ultra-violet radiation were 1.57 in Nov., 1925, 1.51 in Feb., and Apr., 1927, 1.37 in Feb., 1929 and 1.52 in Jan., 1930. The lowest values were 1.00 in June, 1924, 1.24 in July, 1925, 1.28 in April, 1926, 1.18 and 1.12 in Jan. and Sept., 1928, 1.19 in July and Nov., 1929 and 1.10 in July, 1930. The curve is now at the lowest point it has reached since the beginning of the present sun-spot cycle as is also the curve of sun-spot numbers.

Sources of error which might vitiate the results have been looked for in the instrument and the atmosphere, but so far without substantial result. The transmissions of the metallic filters and lens-cells upon which the measurements depend have been checked from time to time and appear to be stationary.

The effect of variability in the ozone content of the atmosphere was investigated by putting an ozone tube in the optical path of the instrument and it was found that the effect is negligible within the range of ozone content observed by Dobson. The general effect of the atmosphere is shown in the lower curve of the figure labelled 'ratio zenith to space'. This is a plot of the mean-monthly ratio of the transmissions of the atmosphere for λ 0.32 μ and λ 0.5 μ as obtained from the plots for each day. There appears to be only a small variation and it seems to have little connection with the variation of ultra-violet solar radiation.

Carnegie Institution of Washington,
Mount Wilson Observatory,
February, 1931.

UNTERSUCHUNGEN ZUR AUFKLÄRUNG DER ÜBERTRAGUNGSVERHÄLTNISSE BEI KURZWELLEN

von E. Quäck.

Die Untersuchungen über die Ausbreitung von kurzen Wellen, soweit sie der Betrieb der Transradio A.G. für drahtlosen Übersee-Verkehr zuliess, haben sich auf folgendes erstreckt:

In der Arbeit 'Hörbarkeitsgrenzen und günstigste Verkehrszeiten bei Kurzwellen auf den einzelnen Überseelinien' im Band 5 1928, Heft 12, der 'Elektrischen Nachrichtentechnik' werden erstmalig auf Grund mehrjähriger Erfahrungen die Beobachtungen dargelegt, die sich aus den normalen Ausbreitungsbedingungen und aus der Verwendungsmöglichkeit der Kurzwellen ergeben. Als wichtigste Feststellungen seien folgende angegeben:

1. Teilt man den Wellenbereich von 10 - 45 m in drei Gruppen ein, und zwar in Tageswellen von 10 - 19 m, in Übergangswellen von 19-25 m und in Nachtwellen von 25 - 40 m, so ergibt sich, dass für einen 24-stündigen Betrieb auf den Überseelinien im allgemeinen eine Tages- und eine Nachtwelle ausreicht. Auf einzelnen Linien, besonders aber auf der Linien Berlin-New York, ist jedoch eine Zwischenwelle für einen 24-stündigen Betrieb notwendig, besonders in den Wintermonaten.

2. Die günstigsten Verkehrszeiten sind von der Entfernung - Empfänger und von der Lage des sie verbindenden Grosskreises und damit im Zusammenhang von der zeitlichen Verteilung der Sonneauf - und Untergänge abhängig.

3. Wenn man die Tageswelle der gemeinsamen Helligkeit, die Nachtwelle des gemeinsamen Dunkelheit und die Übergangswelle den Zwischenzeiten, wo ein Teil des Weges im Hellen und ein Teil im Dunkeln liegt, zuordnet, so stellt man eine Verschiebung bezw. eine

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Verzögerung bezgl. der günstigsten Übertragungsverhältnisse fest. Zwar fällt der Beginn der günstigsten Zeiten bei den Tageswellen für alle Linien und Richtungen auf grosse Entfernungen etwa mit dem Anfang der gemeinsamen Helligkeit des direkten Weges zusammen (siehe 4). Die günstigste Verkehrszeit reicht im Sommer bis weit in die gemeinsame Nachtzeit hinein, im Winter dagegen nur wenig über die gemeinsame Helligkeit hinaus. Liegen Sender und Empfänger auf derselben Halbkugel, so wird die günstigste Wellenlänge innerhalb jeder Wellengruppe mit abnehmender Breite kürzer. Läuft der direkte Weg über den Aequator hinweg, so ist auch eine kürzere Wellenlänge günstig. Die Übergangswellengruppe füllt besonders im Winter Lücken zwischen gemeinsamer Helligkeit und Dunkelheit aus, sie ersetzt jedoch mit gutem Erfolg bei zunehmender Breite die Tageswellen.

4. Der Zustand der Atmosphäre scheint sich allmählich mit der Tageszeit zu ändern bis auf die Zeit des Sonnenaufgangs, wo eine schnelle Veränderung ihres Zustandes eintritt.

5. Die Ausbreitungsbedingungen für die Tageswellen sind im Sommer auch während der gemeinsamen Nachtzeit wegen der geringen Schichthöhe in Sommernächten sehr günstig; es herrscht hier fast der normale Tageszustand des Atmosphäre. Ganz annormal-günstige Verhältnisse bestehen insbesondere für Tages - und Übergangswellen in der Dämmerungszone, wo die Wellen mehrmals um die Erde laufen können. (s. später).

Ferner wurden erstmalig oszillographisch aufgenommene Doppel - und Mehrfachzeichen der Oeffentlichkeit bekanntgegeben in der Abhandlung: 'Neues über die Ausbreitung von kurzen Wellen' im Jahrbuch für drahtlose Telegraphie 28, Seite 177, 1926. Durch diese Veröffentlichung wurde der Nachweis erbracht, dass die theoretisch vorausgesagte Kennelly-Heaviside-Schicht tatsächlich besteht. In einer umfangreichen Abhandlung, betitelt 'Doppel-und Mehrfachzeichen bei Kurzwellen' von E. Quäck und H. Mögel in der E.N.T., Band 6, 1929, Heft 2, wurden viele Beobachtungen über diese hochinteressanten Vorgänge niedergelegt. Auf der Weltkraftkonferenz in Tokio, 1929, wurden sie zum Vortrag gebracht. Als Hauptergebnis der systematischen Messungen sei hervorgehoben, dass der von den Kurzwellenstrahlungen zurückgelegte Weg bei Rechnung mit einer Geschwindigkeit von 300 000 km/sek. stets etwa 3,5 per cent länger ist, als die entsprechende Erdentfernung; die Zeitdifferenzen schwanken nach unserem Messungen nur innerhalb 1 ms, ebenso sind die Zeichenverbreitungen auf grosse Entfernungen nicht grösser als 1 ms. Bei Ganzumlaufzeichen liegen sie meist nur in der Grössenordnung von einigen Zehntel ms. Damit dürfte der Beweis für die alleinige Wirkung der Kennelly-Heaviside-Schicht für die Ausbreitung der kurzen Wellen auf grosse Entfernungen erbracht sein, während die auf kurze Entfernungen festgestellten Nahechos auf das Bestehen einer zweiten Schicht in einigen tausend km Höhe hinzuweisen scheinen.

Ferner sei über diese Beobachtungen noch folgendes gesagt:

1. Doppel- und Mehrfachzeichen wurden in einem Wellenbereich von 14 - 22 m insbesondere dann beobachtet, wenn der Grosskreis Sender-Empfänger die Dämmerungszone durchläuft, in der die Ausbreitungsbedingungen für diese Wellen besonders günstig sind. Sie werden umso günstiger, je näher der Grosskreis Sender- Empfänger an den Polarkreisen vorbeiläuft. Die Zeiten für ihr tägliches Auftreten sind im Winter und Sommer um 12 Stunden verschoben und liegen im Sommer um die Zeit des längsten und im Winter um die Zeit des kürzesten Tages. Dabei ist besonders hervorzuheben, dass die Richtung der Zeichen im Sommer vorzugsweise direkt, im Winter dagegen indirekt, d.h. rückwartig ist.

2. Indirekte Doppelzeichen (d.s. solche, die in umgekehrter Richtung wie das Hauptzeichen um die Erde laufen) können im Bereich von 12 - 22 m auch ausserhalb des Dämmerungsgürtels auftreten, wenn der rückwärtige Weg im Sommer in der ersten Nachthälfte verläuft.

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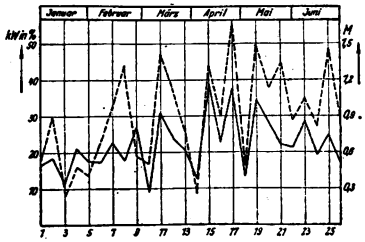
Dann herrscht hier auch bei Nacht ein ähnlicher Zustand der Atmosphäre wie in der Dämmerung.

3. Längere Kurzwellen zwischen 25 und 45 m können auch den rückwärtigen Weg bei Nacht zurücklegen, wenn die Sonneneinstrahlung auf den hellen Teil nicht so intensiv ist. Die über den direkten Weg empfangene Amplitude ist zu dieser Zeit gerade an der Hörbarkeitsgrenze.

4. In der Arbeit wurden 4 verschiedene Grosskreise mit Angabe der Verteilung von Tag, Dämmerung und Nacht graphisch dargestellt, z.B. der Grosskreis Berlin-New York für den 1. Januar und für den 1. Juli. (Abbild.3.p.110)



Abbild 1.
Wochenmittel-Darstellung der Kurzwellen-Störungen und des magnetischen Charakters fur das 1. Halbjahr 1930.

Mann kann aus dieser Darstellung die Belichtung des direkten und indirekten Weges ablesen und sich ein Bild über die Verkehrsmöglichkeiten machen, insbesondere die Zeiten für Doppelzeichen im Voraus bestimmen.

Auch das Studium der Nahechos wurde, soweit der Betrieb es zuliess, systematisch fortgesetzt. 4 Nauener Kurzwellensender mit 12 verschiedenen Wellen besitzen eine Tasteinrichtung für spezielle Punkte von 4/10 000 s Länge. Die Technik der oszillographischen Aufnahmen wurde wesentlich verbessert, insbesondere durch Herabsetzung der Zeitkonstante der Wiedergabeapparate unter 10^{-4} s. Das erste Nahecho lässt im Verlaufe der Tages- und Jahreszeit einen Zusammenhang mit der Sprungentfernung erkennen, während die mehrfachen Nahechos (bis zu 7) uns in der Annahme bestärken, dass in Höhen von 1000 - 3000 km eine zweite Schicht besteht, die wir uns als die Grenzflächen des aus der Geophysik her bekannten Elektronenringstromes vorstellen. Da die Echos oft um ca. 20 ms verbreitert sind, muss auch hier eine starke Zerstreuung stattfinden. Direkte Echos kleiner Amplitude von der KH-Schicht wurden nur gelegentlich gemessen.

Weiterhin erstrecken sich die Untersuchungen auf die Zusammenhänge, die zwischen Empfangsstörungen bei Kurzwellen und die Störungen des magnetischen Feldes der Erde bestehen.* Als wesentliches sei folgendes erwähnt.

Für die Untersuchungen diente als Grundlage eine exakte Statistik der Empfangsstörungen vieler Linien Transradios in Geltow über drei Jahre und eine spezielle Behandlung von vielen Einzelfällen nach Zeitdauer und Amplitude. Als magnetische Unterlagen wurden die internationalen Charakterzahlen von De Bilt, die H-Kurven von Potsdam und in einigen Fällen die H-Kurven von 15 Observatorien verschiedener Erdteile benutzt. Das Ergebnis schliesst sich eng an die Anschauungen von Eckersley an. Die von der

* s. H. Mogel: 'Über die Beziehungen zwischen Empfangsstörungen bei Kurzwellen und den Störungen des magnetischen Feldes der Erde', in der 'Telefunken-Zeitung' Nr. 56, 1930.

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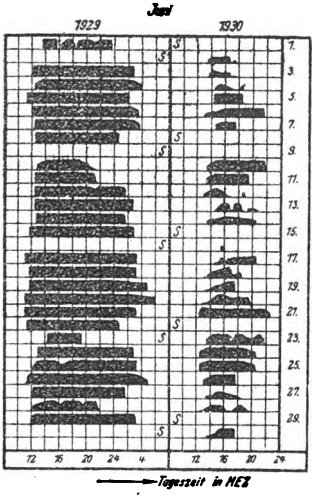
Sonne bei Störungen ausgehenden Strahlungen können entweder langwelliger Art von geringer Geschwindigkeit oder kurzwelliger Art von hoher Geschwindigkeit sein. Meist sind beide Strahlenarten gleichzeitig vorhanden. In gewissen Fällen lässt sich jedoch ihr Wirkung auf Erdfeld und Kurzwellenempfang getrennt erkennen. Die ersteren werden nämlich vom Erdfeld abgelenkt und treten in grossen Höhen in die Gegend der magnetischen Pole in das Erdfeld ein. Sie rufen die magnetischen Störungen und die allgemeinen grossen Kurzwellenstörungen hervor, die auf der ganzen Erde auftreten, jedoch bei abnehmender Entfernung der Grosskreise von den Polen mit stetig abnehmender Stärke und Zeitdauer. Wir haben sie Langstörungen genannt. Die Kurzwellenschwächungen setzen dabei mit einer Verzögerung von mehreren Stunden gegen die magnetischen Störungen ein und aus-Bei Kurzwellenlinien grosser magnetischer Dichte, wie Berlin-New York und Berlin-Japan, folgt jedoch die Empfangsstörung zu über 90 per cent der magnetischen Tätigkeit. Bei längere Zeit enthaltenden Sonnen- und magnetischen Störungen, z.B. wie im vergangenen Jahre von April bis Oktober, findet auf Linien grosser Dichte am Tage eine Verschiebung der günstigsten Wellenlänge vom Tageswellenbereich nach den Übergangswellen zu statt. Wir haben z.B. während der schlechten Verhältnisse im vergangenen Jahre von New York anstelle der fast völlig unbrauchbaren 16 m Gruppe (s. Abb. 2) eine 20 m Welle mit Erfolg für den Betrieb verwendet. Grosses Interesse verdient das völlige Versagen der kurzen Wellen auf der Linie Europa - Amerika in der Zeit vom 8. - 12. August, 1930, fur welchen Vorgang eine Erklarung noch nicht vorliegt.*



Abbild. 2.
Vergleich der Empfangs-Amplituden der 16 m- Wellengruppe von New York im June 1929 und in Juni 1930 in Gultow.

Die kurzwelligen schnellen Strahlungen dringen nun im Gegensatz zu den langsamen sehr tief in die Atmosphäre ein, und zwar nur auf der belichteten Erdhälfte, da sie vom Erdfeld nicht abgelenkt werden; sie rufen im gesamten Kurzwellenbereich und noch weit darüber hinaus starke Schwächungen bis Null hervor, die jedoch

* s. E. Quack: 'Versagen der kurzen Wellen auf der Linie Europa-Nordamerika in der Zeit vom 8.-12.August 1930'. in der 'Elektrischen-Nachrichten Technik', Band 8, Heft 1, 1931.

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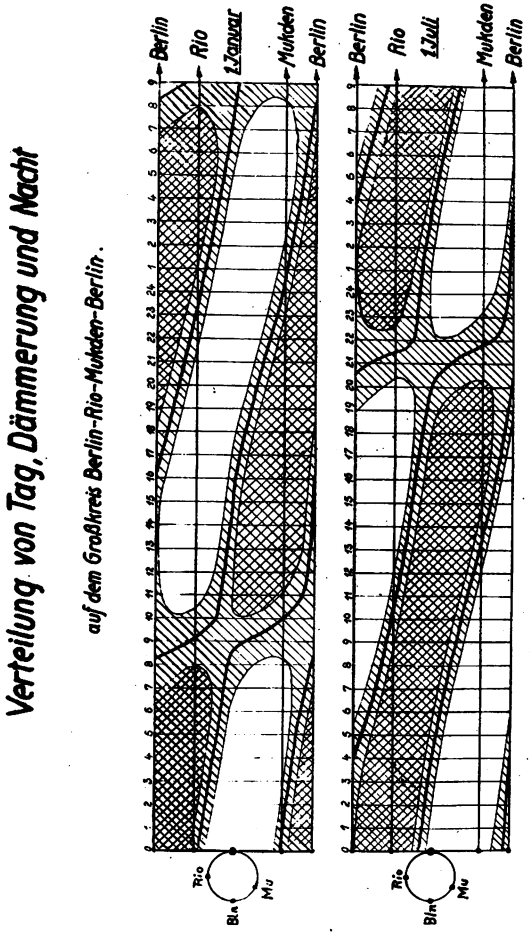
sehr schnell innerhalb weniger Minuten gleichzeitig ein- und aussetzen. Wir bezeichneten sie mit Kurzstörungen. Sie nehmen umgekehrt wie die Langstörungen nach den Polen zu an Intensität ab. In gewissen Grenzfällen, wo die allgemeine magnetische Tätigkeit ruhig ist, zeigte das Erdfeld den völlig gleichzeitigen und typischen Verlauf einer Bay-Störung von einigen Gamma-Feldstärke-Änderungen, jedoch nur auf der belichteten Erdhälfte oder auf Teilen hiervon.



Grosser Aufwand an Antennen usw. auf der Sende- und Empfangsseite kann bei mittleren und starken Langstörungen noch einen mässigen Betrieb zulassen, während bei starken Kurzstörungen bei Aufwendung dieser Mittel im allgemeinen keine Verständigung möglich ist. In diesen Fällen hilft dann nur der Einsatz der langen Wellen. Die Arbeit enthält weiter Beobachtungen mehrerer Kurzwellen-Phönomene unter dem Einfluss der normalen und der unregelmässigen Variationen der Atmosphäre im Zusammenhang mit Sonnenstörungen.

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THE LIGHT OF THE NIGHT SKY AND ITS ANNUAL AND LONG PERIOD VARIATIONS.

by Lord Rayleigh.

The series of observations carried out in England on the photometric intensity of the night sky in England have been continued for the three years which have elapsed since the last report, following the same methods, i.e. comparison of the light as filtered by a coloured screen against a standard source of light consisting of a spontaneously luminous radioactive substance. The coloured screens are arranged to transmit independent regions of the spectrum, and are called

red, auroral, blue.

The auroral screen is arranged to isolate the green auroral line 5577 as nearly as possible, but in fact although the best was done in this way, an important, perhaps usually a major part of the light transmitted is due to the background of the spectrum on which this line is superposed.

The three components isolated by the three screens show comparable variations in general though not complete sympathy with one another, but the auroral component gives the most marked and definite results, and has been observed for the longest time. It alone will be considered here.

The table below reproduces and brings up to date the mean values for each month before given.

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.
1922-3	..	..	..	..	..	..	-0·5	0·0	-1·9
1923-4	+0·0	+0·3	+0·7	+0·0	-2·2	-2·2	-1·6	-0·3	-1·7
1924-5	+1·0	+0·7	+1·6	-0·9	-0·8	-1·5	-1·2	-0·8	-1·8
1925-6	+0·8	+0·9	+0·8	+1·5	+0·0	+0·5	-0·3	-0·4	+0·0
1926-7	+0·5	+0·8	+1·3	+1·1	-0·4	-0·7	+0·0	+0·8	-0·5
1927-8	+2·0	+1·2	+1·8	+0·9	+1·0	-0·3	-0·7	-1·0	-1·2
1928-9	+1·8	+2·7	+3·7	+1·9	+1·6	+0·2	+1·6	+0·8	-0·2
1929-30	-	+0·5	+2·4	+2·1	+0·4	+1·0	+0·1	+0·2	-0·9
1930-31	+1·3	+2·2	+0·8	+1·1	-0·1	+1·1	-1·2	+0·2	
Sum ...	+7·4	+9·3	+13·1	+7·7	-0·5	-1·9	-3·8	-0·5	-8·2
Mean ..	+1·1	+1·2	+ 1·6	+1·0	-0·1	-0·2	-0·4	-0·1	-1·0

The maximum about October is still very apparent in the individual observing season, and comes out most strikingly in the mean curve for all the seasons given in Fig. I. The rise in March is still apparent, but the lapse of time, and increase of material has tended to smooth it out, and it is now much less pronounced than in the curve published in the last report.

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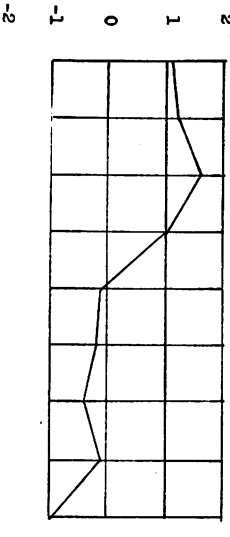

Fig. I.

We pass next to the question of long period variations, following (probably) the solar cycle. The following table gives the annual mean, i.e. the mean of the monthly averages, taking only the observing months into account (summer months, May, June, July excluded).

Year.	Sum.	Mean.
1923	-3·6	-0·45
1924	-4·2	-0·47
1925	-1 3	-0·14
1926	+3·1	+0·34
1927	+6·5	+0·72
1928	+8·5	+0·94
1929	+9·3	+1·03
1930	+5·7	+0·63

These results are shown graphically in Figure 2. The eight years now available give a much more definite notion than previously of what is likely to be the course over the complete solar cycle. A maximum in 1929 seems to have followed the minimum in 1923, and the same is approximately true of the sunspots. Another three years of observation should put the matter almost beyond doubt.

Incidentally, the fact that the maximum has been passed removes any possible suspicion that the initial increase could be attributed to a loss of brightness in the self maintained radio active standard of light (potassium uranyl sulphate).

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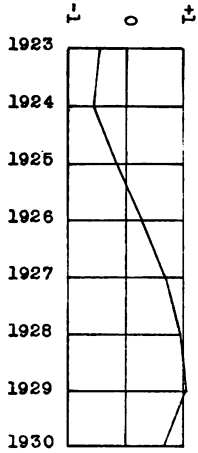

Fig. II.

The above account has reference to my own observations made in England. Observations have also been continued at Canberra and at the Cape. A discussion of all of these has been given by Dr. Spencer Jones (Proc.Roy.Soc.A. Vol.126,p.246,1930), who has made a harmonic analysis of the variations, assuming an annual and a semiannual term. It is a puzzling feature that the Cape and Canberra observations do not show the regular increase from sunspot minimum to sunspot maximum which is revealed in the English observations: but the further continuation of the series cannot fail, it would seem, to clear up the apparent discrepancy.

A determination has been made of the absolute intensity of the auroral line in the night sky, (Proc. Roy. Soc.A. Vol.129, p.458, 1920). In this work the standard instrument used in measuring the green auroral light of the night sky was calibrated. The instrument uses a special filter designed to isolate the green auroral line as nearly as possible. If the transmitted light is assumed to consist entirely of λ 5577, the brightness corresponding to the zero reading of the instrument is found to be

$8{\cdot}65 \times 10^{-5}$ candles per square metre,

which is an upper limit to the brightness of λ 5577 in any source which gives this zero reading.

In fact, the light transmitted by the filter consists in part of the green line, and, in part, of continuous background. The fraction attributable to the former is variable; its most common value is estimated at 0·37.

The brightness of the line then becomes

$3{\cdot}2 \times 10^{-5}$ candles per square metre.

This is the zero reading of the standard photometer, but (as it happens) also corresponds very closely with the mean observed brightness on the night sky, corrected to the zenith. The energy required to maintain it is

6·4 ergs. per second per square metre,

and the number of atomic transitions required to supply this energy is

$1{\cdot}81 \times 10^{12}$ per second per square metre.

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THE CORRELATION OF SOLAR AND LUNAR PHENOMENA WITH THE IONIZATION OF THE EARTH'S ATMOSPHERE.

By Dr. Harlan T. Stetson,
Director of Perkins Observatory.

Studies in the correlation of solar activity with radio reception carried on at Cambridge, Massachusetts, in collaboration with the work of Mr. Greenleaf W. Pickard, have shown that from 1926 to 1928 the intensity of radio reception received at Boston from WBBM, Chicago, at a frequency of 770 kilocycles, has been in general definitely weaker at times of much solar activity and stronger with a decrease in sunspot numbers. A secondary cycle of approximately fifteen months has persisted throughout the recent maximum, and led to the prediction of a secondary maxima in sunspot numbers in the latter part of 1929 and 1930 which have been fulfilled with an expected decrease in intensity of radio reception over the path mentioned.

With the establishment of a research program at the Perkins Observatory, Delaware, Ohio, in 1929, apparatus removed from Cambridge, together with additional equipment, was set up at the Perkins Observatory. A year's record has now accumulated giving quantitative measurements of radio reception from WBBM as received at Delaware over a distance of some 430 kilometers.

An analysis of data at hand shows that reception at Delaware has been, in general, less intense with each increase in solar activity during the year just passed. Beginning with December, 1929, signals have also been received and measured from WJZ, New Jersey, a distance of 1500 kilometres. The true bearing of the Chicago station is approximately north 65° degrees west, and of WJZ due east from Delaware.

The present interpretation of data suggests that the ionization level of the Kennelly-Heaviside layer is depressed at times of solar activity and rises with a diminution of sunspot numbers. A careful analysis of correlation curves seems to show a more definite correspondence between the radio curve and the inverse sunspot numbers than with a curve of ultra violet radiation intensities. This favors the hypothesis that sunspots may serve as electro-magnetic centers for guiding emitting electrons earthwards, and distinctly favors the corpuscular hypothesis.

Recent studies of radio data at the Perkins Observatory appear to show a remarkable decrease in the intensity of signal strength when the moon is above the observer's horizon as compared with corresponding signal strengths when the moon is below the horizon. The hypothesis is tentatively advanced that the moon is at a different electrical potential than that of the earth. Interpreting the decreased radio reception as a function of high altitudes of the moon as an effect analogous to solar activity, it is believed that the ionization level of the earth's atmosphere which turns back the radio waves is relatively depressed when the moon is above the horizon. It is suggested that a negative charge on the moon may account for the observed phenomena.

Apparatus is now being installed at the Perkins Observatory which will make possible a daily survey of the critical ionization level for the 20, 40 and 80 meter bands. A broadcasting station for high frequencies is soon to be set up at the Warner and Swasey Observatory in Cleveland, Ohio, for

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the express purpose of maintaining control signals which will be recorded at Delaware.

For the coming year we have also the assurance that trans-Pacific reception is to be undertaken at Yenching, Peiping, China. The growing importance of the measurement of ionization levels by radio reception as a problem in cosmic physics calls for concerted efforts world wide in scope.

As it appears that the measurement of radio reception may prove of inestimable value in the studies of solar activity, the Perkins Observatory and its Director believe that a definite program of international cooperation for this purpose should be duly considered at the forthcoming meeting of the appropriate sections of the International Astronomical Union in Cambridge in 1932.

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1. H.T. Stetson and G.W. Pickard, 'On the present sunspot maximum and correlation with radio reception', Pop. Astr., 37: 388-390 (1929).
H.T. Stetson, 'Influence of sunspots on radio reception' Frank. Inst., 210, 403-419, (1930): (Perkins Obs.Misc.Sci.Papers, Reprint No.3)

2. G.W. Pickard, 'Correlation of radio reception and solar activity with terrestrial magnetism'. Proc. Inst.Radio Eng., 15, 83-97, 749-766, (1927) Also Bull. National. Res. Coun., No.61, 133-145 (1927).

3. A. Schuster, 'Influence of the planets on the formation of sunspots', Proc.R. Soc., 85, 309-323, (1911).

4. H.T. Stetson, 'On the correlation of radio reception with the moon's position in the observer's sky', Jour. of Terrestrial Magnetism and Atmospheric Electricity, pp.1-6, March, 1931. also (Perkins Obs. Misc. Sci. Papers, Rep. No.8).

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VARIABILITY OF SOLAR ROTATION.

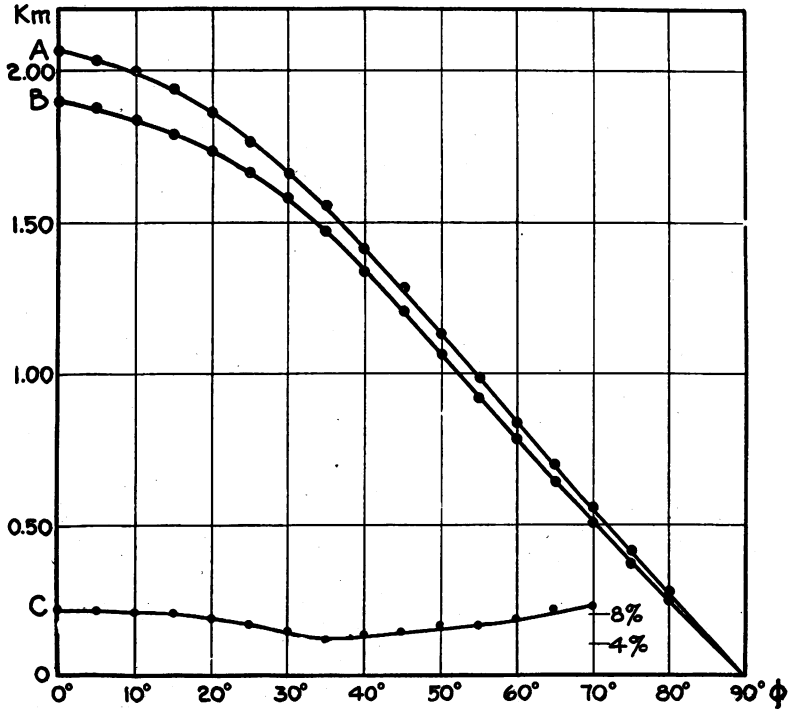
By Charles E. St. John.

It has become increasingly evident that the rotetion of the sun, as determined from spectroscopic observations, is not constant. This is not surprising since the Fraunhofer lines used in such observations are produced at different levels in an atmosphere subject to disturbances which may be irregular and of short duration or long enduring. The effect seems to indicate that something quite fundamental is concerned in the phenomena.

The first indications that the rotation of the solar atmosphere might be variable appeared in the differences between the values obtained by different observers at different epochs. As these variations might be referred to errors in measurement, to differences in apparatus and methods of procedure, or to the personal equations of the observers, a series of observations and measurements was begun at Mount Wilson Observatory in 1914 in which the instrumental equipment and personnel should be the same for a sun-spot cycle.

For the years 1919.5 to 1921.5 spectrograms of limb and center have been taken from 0° to 85° latitude and reduced. The results when compared with those of Adams and Lasby for 1906.5 to 1908.5 show values for Adams and Lasby minus St. John and Ware approximately eight per cent greater for the earlier measures at all latitudes. The results are shown graphically in Plate I.

ROTATION OF THE SUN.



A. Adams and Lasby 1906.4-1908.5
B. St.John and Ware 1919.5-1921.5
C. Percentage of A over B

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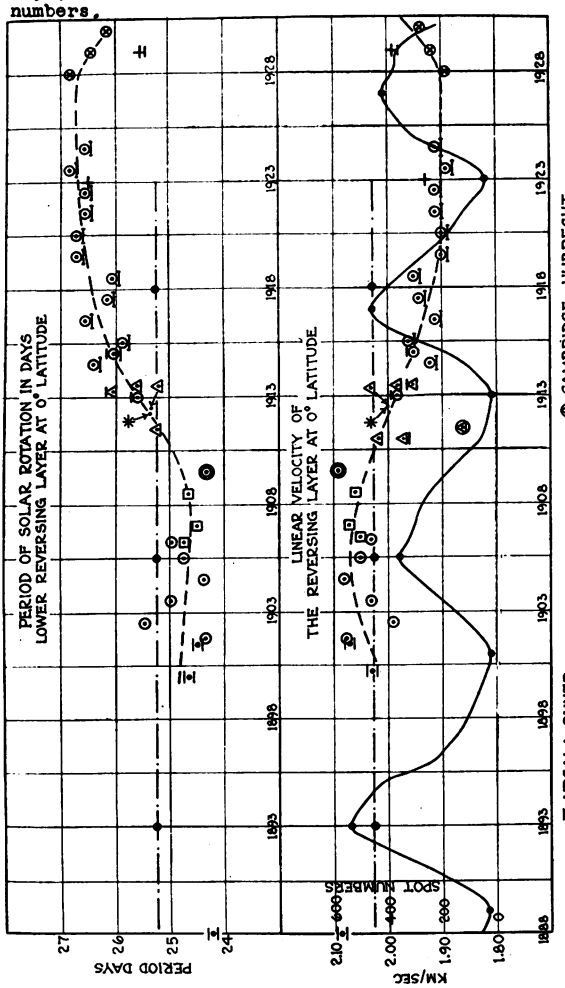
Since the percentage change was so nearly the same at all latitudes, it was decided, because of the labor of reduction, to confine exploratory series mainly to the equator and to continue the observations under the same conditions for a sun-spot cycle. As the rate of rotation showed a continued decrease through the eleven years, the observations have been carried on through 1930, a period of eighteen years. For ten years 1919-1928 the rate of rotation has been a minimum with a period of 26.75 days and a linear velocity of 1.90 km/sec. compared with 24.75 days and 2.07 km/sec. in 1907.5 During 1929 and 1930 the linear velocity has risen to 1.95 km/sec. and the period has decreased by 0.6 day. One looks to 1931 and the following years with added interest.

The available spectroscopic data are assembled in sections A and B of Table I and the sun-spot data for the same years in sections C, D, and E. The first column gives the station, the second column the observers, the third, fourth, fifth and sixth columns, the epoch, linear velocity, angular velocity and period respectively. The data of sections A and C are graphically shown in Plate II where the abscissae are dates. In the upper half the ordinates are periods in days; in the lower the ordinates are linear velocities and sun-spot numbers.



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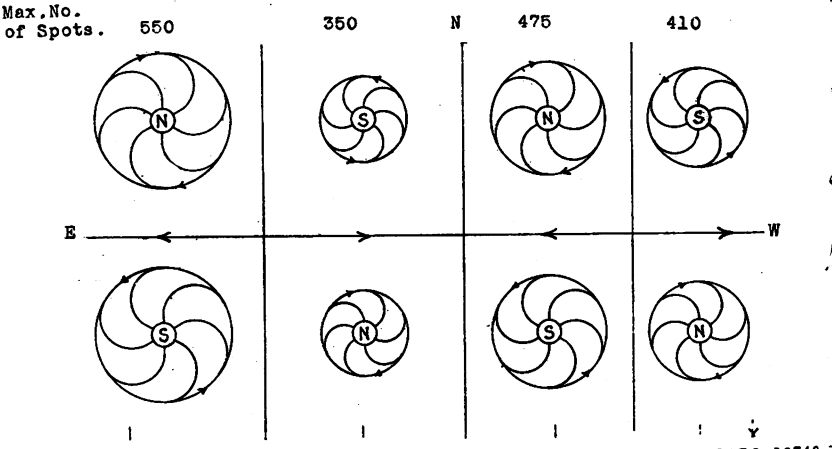
The spectroscopic observations show a progressive change in the rotation during the last thirty years which is not accounted for by errors in the observations. On the other hand the rotation of the sun determined from long-lived sun-spots by the Greenwich observers shows no variation during the same years.

During a sun-spot cycle the polarity of spots in the northern and southern hemispheres is opposite, the polarity alternating from cycle to cycle. On the assumption that the direction of whirl changes with change of polarity one can deduce currents in the lower reversing layer setting eastward during one cycle and westward during the preceding and the following cycle as in any cycle the northern and southern spots conspire in their current producing action. On this assumption a mean period of approximately 23 years would be expected in the run of rotation values. The linear velocity was a maximum near 1906-7 and a second maximum should then occur near 1929-30. Though the curve of linear velocity is rising rapidly in 1929 and 1930, it is too early to reach a definitive result. Differences in phase between spot numbers and the changes shown in the rotation of the reversing layer are to be expected. The phase of the equatorial currents would depend upon the number, size and activity of the spots and their distance from the equator. The spots of new cycles appear at high latitudes and are few in number. Their effect would be small in overcoming the equatorial currents of the preceding cycle whose effect would tend to carry over. Only in the mean of a long series of observations could the average double spot-cycle be anticipated. (Diagram I).



DIRECTION OF ROTATION IN SUN-SPOT VORTICES AS DEDUCED FROM EQUATORIAL CURRENTS IN THE REVERSING LAYER.

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In looking for a connection between changes in the rotation of the lower reversing layer and sun-spots it is surprising to find that no change in the period of rotation from cycle to cycle is shown by the Greenwich sun-spot observations. For any given cycle the mean value is based upon the life-history of the spots which includes the first two or three days when the spot is moving westward in longitude at the rate of about 1°0 a day; the days when it is moving with the mean velocity assumed for its latitude, and the days in its later life when it is moving slowly eastward. (Table I Section D) Manifestly the agreement between cycles means a consistent use of the data but just what this tells of the rotation of the photosphere is not clear. The period of rotation calculated for the first two days in the life of a 'leader' spot is 1.7 days shorter than the adopted average and 1.8 days shorter than for spots 20 days or more old. These results refer to the long-lived 'leader' spots in bipolar groups. The 'follower' spots are moving slowly eastward during their whole life. (Table I Section E). As a result of the peculiar motions of the components of bipolar groups, the separation of leader and follower increases at first by 1°15 per day and then less rapidly but continuously during the life of the follower spots, which on the average is 11 days, while the life of the 'leader' spots is from 25 to 60 days.

The ideal norm for the rotation would be that of the sun's photosphere, which has been assumed to be that given by sun-spots, but the westward and eastward movements of leader spots and the continuous eastward movement of follower spots (Table I.Section E) point to a drift of spots in the photosphere rather than to streaming of the photosphere material. The average rotation shown by spots can hardly be precisely that of the photosphere but probably is the best norm available.

The height of the lower reversing layer above the photosphere is 300-500 km. From observations, its linear velocity in 1906 was 0.06 km/sec. greater than that of the photosphere and in 1918 0.10 km/sec. less, indicating that during the cycle 1901-1913 the streaming of the reversing layer was 0.06 km/sec. from east to west, and during the following cycle 0.10 km/sec. from west to east. Interpreted as connected with the direction of whirl in the spot-forming vortex, this would indicate a counter clock rotation for the spots in the northern hemisphere during the cycle 1901-13, and clockwise in the following cycle. During the cycle beginning in 1923, the linear velocity given by the reversing layer should increase as it apparently does but whether it will persist is as yet unknown.

A correlation between direction of whirl in the spot vortex and currents along the sun's equator would be of great interest in its bearing upon the sign of the electric charge in the spot-forming vortex.

The variation in the period of the sun's reversing layer, the alternation in the polarity of spots from cycle to cycle, and the eastward and westward movements of the spots in the photosphere are indices of changes important and possibly related.

From section B of Table I it appears that the high-level chromosphere shows a similar variation in rotation values. For Hα Adams and Lasby found in 1907 a linear velocity of 2.11 km/sec. Evershed in 1923 found 2.07 km/sec. linear velocity, a decrease of 0.04 km/sec., while between the same dates the reversing layer showed a decrease of 0.17 km/sec. Abetti and Novakova in 1928.8 obtained 2.07 km/sec. for dark $H\alpha_3$ and 1.95 km/sec. for the mean of the bright $H\alpha_2$ components of the double reversal just off the limb. The agreement with Evershed is consistent with the results for the reversing layer whose rotation during the interval was uniformly low. The low level bright $H\alpha_2$ shows a rotation slower than the photosphere as given by sun-spots, agreeing in this respect with the reversing layer at the same epoch and pointing again to an eastward drift

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carried over from the preceding and possibly more effective cycle.

For Ca^+, λ3950, St. John and Ware obtained in 1916 a linear velocity of 2.20 km/sec. Evershed in 1923 found 2.13 km/sec. while the reversing layer showed a decrease of 0.05 km/sec. The high-level chromosphere apparently shares to a measureable degree the slowing down of the reversing layer. Further observations are advisable to determine the matter more precisely, as it is important in seeking the location of the cause of the phenomena. At best it is a complicated question. The direction of the great high-level whirls shown on Hα spectroheliograms follows the law of terrestrial cyclones. These whirls would then tend to produce drifts of the chromosphere in one direction.

This problem will be taken up at Mount Wilson Observatory and because of its importance it is hoped that it will be put on the program at other observatories and that measures on the reversing layer at 0° latitude will be carried on at other observatories. For the observations on the reversing layer the red region near λ6300 is employed at Mount Wilson because of the control over observing conditions furnished by the atmospheric lines.

On the assumption that the average rotation from spots represents most nearly that of the photosphere the order of heights above the photosphere is as in Table III. Table III indicates in broad outline a probable order of level. The flocculi and faculae are found between the spot-level and the chromosphere but the data are insufficient to fix the relative levels of faculae and flocculi.

It seems necessary to interpret the periodicity shown by the reversing layer as due to periodic equatorial currents. It cannot be referred to differences in level at different epochs, for in 1918-1928 its level as determined from its velocity and period would place it below the photosphere.

The observations on faculae and flocculi cover only one spot cycle, 1901-1913, in common with the spectroscopic measures. The observations on faculae and flocculi at the maximum of the preceding cycle, 1890-1901, show no differences between the cycles within the probable precision of the measures.

The important question whether the rotation given by faculae and flocculi shows a periodicity similar to that of the reversing layer could be determined from measures during the interval 1918-1928 for which the material exists in several observatories. Such data might delimit the region of the periodic currents in the reversing layer and aid in assigning their cause.

Mount Wilson Observatory.
February 24, 1931.

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TABLE I.

Rotation of the Sun.

A. From Spectroscopic Observations of the Reversing Layer at 0° Latitude, Height 300-500 km.

Station	Observer	Epoch	Linear Velocity	Angular Velocity	Period in days	Remarks
			km/sec			
Upsala	Duner	1888	2.09	14°84	24.26	
		1900	2.03	14.41	24.67	
		1901.5	2.07	14.70	24.50	
		1901.7	2.08	14.77	24.37	
		1902.5	1.99	14.13	25.48	
		1903.5	2.03	14.41	24.98	
Edinburgh	Halm	1904.5	2.08	14.77	24.37	
		1905.5	2.05	14.55	24.74	
		1906.3	2.03	14.41	24.98	
		1906.4	2.05	14.55	24.74	
Mt. Wilson	Adams and Lasby	1907.0	2.07	14.70	24.50	
		1908.5	2.06	14.62	24.62	
Edinburgh	Storey and Wilson	1909.5	2.09	14.81	24.31	
Ottawa	Plaskett,J.S.	1911.0	2.02	14.34	25.10	
Ottawa	De Lury	1911.0	1.97	13.99	25.72	
Cambridge	Hubrecht	1911.0	1.86	13.21	27.36	
Ottawa	Plaskett,J.S.	1912.5	2.00	14.20	25.36	
Allegheney	Schlesinger	1912.5	2.00	14.20	25.36	
Kodaikanal	Evershed and Royds.	1913.0	1.95	13.84	26.04	
Ottawa	Plaskett,H.H.	1913.0	1.98	14.06	25.61	
Mt.Wilson	St.John and Ware	1914.5	1.92	13.63	26.41	
Ottawa	Plaskett,H.H.	1915.0	1.95	13.84	26.04	
Mt. Wilson	St.John and Ware	1915.5	1.96	13.92	25.87	
"	"	1916.5	1.91	13.56	26.55	
"	"	1917.5	1.94	13.77	26.14	
		1918.5	1.95	13.84	26.04	
		1919.5	1.90	13.49	26.69	
		1920.5	1.90	13.49	26.69	
		1921.5	1.91	13.56	26.55	
		1922.5	1.91	13.56	26.55	
Kodaikanal	Evershed	1923	1.93	13.60	26.47	
Mt. Wilson	St.John and Ware	1923.5	1.89	13.42	26.83	
		1924.5	1.91	13.56	26.55	
Mt. Wilson	St.John and E.F.Adams.	1928	1.89	13.42	26.83	
		1929	1.92	13.63	26.41	
Arcetri	Abetti and Novakova	1929	1.99	14.1	25.5	
Mt.Wilson	St.John and E.F.Adams.	1930	1.95	13.77	26.14	

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TABLE I. Continued.

B. From Spectroscopic Observations of the Upper Chromosphere at 0° Latitude, Height Ca 4227, 5000 km, Hα 12,000 Ca^+ 3950, 14,000.

Station	Observer	Epoch	Linear Velocity km/sec.	Angular Velocity	Period in days	Remarks
Mt.Wilson	Adams and Lasby	1907 1907	2.09 2.11	14°.9 15.0	24.16 24.00	Ca 4227 Hα
Kodaikanal	Evershed	1923	2.07	14.7	24.49	Hα
Arcetri	Abetti and Novakova	1929	2.07	14.7	24.5	Hα
Mt.Wilson	St.John and Ware.	1916	2.20	15.6	23.05	Ca^+ 3950
Kodaikanal	Evershed	1923	2.13	15.0	24.00	Ca^+ 3950

C. From Long lived 'Leader' Spots at 0° Latitude.

Greenwich	Dyson	1879-1884	2.02	14.35	25.08	Cycle I
		1889-1901	2.02	14.38	25.03	Cycle II
		1901-1913	2.03	14.39	25.02	Cycle III
		1913-1923	2.03	14.39	25.02	Cycle IV

D. From Longlived 'Leader' Spots at 15° Latitude. Life 25 to 60 days.

Greenwich	Dyson	1879 to 1923	2.00	14.2	25.36	Average Spot.
			2.14	15.2	23.68	First two Days
			1.99	14.14	25.46	After 20 Days.

E. From Shortlived 'Follower' Spots. Average Life 11 days.

Greenwich	Dyson	1879 to 1923	1.98	14.07	25.59	First two Days
			2.00	14.2	25.36	End of Life.

TABLE II

Rotation from Spots, Faculae and Flocculi

A. From Sun-spots.

Station	Observer	Epoch	Linear Velocity km/sec	Angular Velocity	Period of Days
Redhill	Carrington	1853-1861	2.03	14°42	24.97
Potsdam	Spoerer	1861-1871	2.02	14.35	25.09
Paris	Tisserand	1874-1875	2.02	14.32	25.14
Greenwich	Maunder	1879-1901	2.03	14.44	24.93
Greenwich	Dyson	1879-1923	2.02	14.37	25.05
Mean			2.02	14.38	25.02

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TABLE II Continued.
B. From Faculae.

Station	Observer	Epoch	Linear Velocity	Angular Velocity	Period of Days	
			km/sec.			
Pulkowa	Stratonoff	1891-1893	2.06	14.62	24.62	Faculae
26 - Se	Chevalier	1906-1908	2.08	14.74	24.42	Faculae
Mean			2.07	14°68	24.52	

C. From Flocculi.

Kenwood	Hale and Fox	1893-1894	2.07	14.70	24.49	Calcium
Yerkes	Fox	1903-1908	2.04	14.56	24.79	Calcium
Mt.Wilson	Hale	1906	2.03	14.42	24.97	Calcium
Potsdam	Kempf	1906	2.04	14.49	24.84	Calcium
Mean			2.05	14°54	24.77	
Mt.Wilson	Hale	1906	2.06	14°6	24.66	Hδ Hydrogen

TABLE III.

Relative Levels of Photosphere, Flocculi, Faculae and of the Chromosphere.

		Linear Velocity at Lat.0°	Angular Velocity.	Period in days.	Mitchell's Heights.
		km/sec.			
Photosphere sun-spots		2.02	14°38	25.02	
Ca^+ Flocculi		2.05	14.54	24.77	
Hδ Flocculi		2.06	14.6	24.66	
Faculae		2.07	14.74	24.52	
Ca λ4227		2.09	14.9	24.16	5,000 km
Hydrogen Hα	1907	2.11	15.0	24.00	12,000 km
Hydrogen Hα	1923	2.07	14.7	24.49	12,000 km
Hydrogen Hα	1929	2.07	14.7	24.5	12,000 km
Ca^+ λ 3950	1916	2.20	15.6	23.05	14,000 km
Ca^+ λ 3950	1923	2.13	15.00	24.00	14,000 km

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AURORAL RESEARCH

By

Carl Størmer.

There are a series of problems on aurora which can best be solved by simultaneous observations from stations well distributed throughout the whole region from which aurorae are visible. One of the principal aims of the coming 'International Polar Year' 1932-33 is to get such observations. A detailed 'Memorandum of auroral work during the polar year, 1932-33', has been elaborated by the cooperation of Dr. Stagg, Dr. La Cour and myself and will shortly be published. The following are among the principal problems there considered -

1. To find the simultaneous distribution of aurora over the Earth's surface.

2. To find the extent of individual auroral arcs.

3. To find the changes which may be in progress at other places when an important change takes place in the form and position of an aurora at one station, as, for example, whether a sudden disintegration from a homogeneous arc to rays takes place simultaneously throughout the arc.

4. To find the time of appearance and disappearance of pulsating patches and flaming aurora.

5. To find the location of the extreme limit to north or south (or normal to the general direction of homogeneous arcs) of individual displays.

6. To measure by photographic methods the height of the aurora in places where such measurements have not yet been made, especially inside the auroral belts, near the Earth's magnetic axis, and in the Antarctic.

7. To get reliable photographic measurements of the most remarkable low aurorae, which are reported as extending down almost to the Earth's surface, but which seem to be very rare. If such aurorae really exist they must be essentially different from those hitherto photographed, whose lower limit in the atmosphere is about 80 km.

The relations between aurorae and kindred phenomena, such as solar activity, magnetic disturbance, earth currents, radio propagation and the physical conditions of the highest atmosphere, present a large field of research which cannot be detailed here. A very careful study of the auroral spectrum for different forms, especially for sunlit aurorae, and a comparison with suitable physical experiments would be of special importance. For the many problems here encountered I may refer to my paper: 'Ueber die Probleme der Polarlichtes, (about 100 pages with 70 figures), which is now being printed by Akademische Verlagsgesellschaft, Leipzig.

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THE STUDY OF THE PROPAGATION OF AIRWAVES TO GREAT DISTANCES: PROGRESS SINCE 1928.

By

F.J.W. Whipple.

1. In an article published in the Second Report of the Commission for the Study of Solar and Terrestrial Relationships I gave a summary of investigations of the propagation of airwaves to great distances. In the present article recent progress in such investigations is discussed.

2. The Oldebroek Explosion October 28th 1922. The explosion at Oldebroek in Holland is of special interest as being the first arranged for the sake of the investigation of its audibility at great distances. The quantity of explosive, ammonium perchlorate, was 5 tonnes. A full account of the observations was published[x] by Dr. E. van Everdingen in 1929. The minimum distance of "abnormal" audibility was about 157 km. to Northeast. In the opposite direction the minimum was 193 km. The upper air observations sufficed to demonstrate that the abnormal audibility could not be explained by the refraction of sound in the troposphere.

There were numerous observers at very great distances, notably in Austria. Dr. J.N. Dörr, who collected the observations in that country, regarded the transmission of sound from Oldebroek as far as Vienna (868 km.) as established. There are however larger discrepancies in the times reported by the Austrian observers and in van Everdingen's opinion the evidence is not good enough to demonstrate the occurrence of such an unlikely event.

3. Research in Germany. Experiments made in Germany from May 1923 to March 1929 are detailed in two reports prepared by H. Hergesell and P. Duckert of the aeronautical observatory at Lindenberg.* During that period there were no less than 346 experimental explosions. To begin with large quantities of explosive were used and the observations were mainly by ear but by 1928 twenty-nine instruments, mostly of the pattern invented by Prof. Kühl and known as the undograph, were in use and good results were obtained from the detonation of comparatively small quantities of explosive, 300 kg. and 150 kg. being adopted as the standard weights in the latest experiments. In 1928 the undographs were placed approximately on a line passing from Northeast to Southwest through Jüterbog where the explosions were produced. Three experiments were made with this distribution of stations. The results are exhibited in the following Tables. Instead of copying the time of transmission of each of the waves which were recorded I have given the 'delay', i.e., the excess of the time of transmission above the time of passage of sound close to the ground. For this purpose a rough average of the prevailing temperatures has been computed and the

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x K.Ned.Met.Inst. Medelingen en Verhandelingen 31 (1929).

* Die Arbeiten das Preuss.Aeronautischen Observatoriums bei Lindenberg. Wiss.Abh. XVIB (1927) and XVID (1929).

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Table 1. Observations of Explosions at Jüterbog.

Date No. of Rounds Temperature Velocity of Sound	Observing Stations	Dist. Km.	Normal Time Sec.	Delay in Seconds Means for one to six rounds
	SW.			
	Leipzig	90	262	64
17 July 1928	Heinersdorf	201	584	116,118,121
	Rodacherbrunn	208	605	116,119,122
	Bamberg	283	823	112,116,121,126,138,147?
6 rounds	Rothenburg	358	1041	100,104,109,113,119, 141,161
	NE.			
295°A	Kunersdorf	120	349	0, 6
	Schlochau	344	1000	14, 69, 245
.344 km/sec.	Danzig	455	1322	247,275
	Königsberg	578	1680	-50, -37,66,186, 258
	NE.			
	Königsberg	578	1758	349,456
	Braunsberg	523	1592	258,350
19 Dec 1928	Schlochau	344	1047	-17,-2 153,171,246,316
	Flatow	309	941	-12 170,297,362
4 rounds	Schneidemühl	281	855	7 83,88, 161,170, 365
	Schönlanke	261	794	163,173
	Kreuz	230	700	-3 60?70, 161,165,168,350?
	Friedeberg	196	597	8,11,61
269°A.	Kunersdorf	120	366	5 83,84,85
	Lindenberg	79	237	7
.3283 km/sec				
	SW. Normal waves only. Maximum "delay" 19 sec.			
	NE.			
	Braunsberg	523	1552	-13,-6 259?(first round)
26 Mar. 1929	Schlochau	344	1022	293
	Flatow	308	915	20 112, 494
	Schneidemühl	281		Smooth curves.
4 rounds	Schönlanke	261	775	114,269
	Friedeberg	196	582	110,216
283°A.	SW.			
	Oppurg	172	512	17,27,62,72
.3368 km/sec.	Seebach	182	542	81 (first round)
	Rodacherbrunn	208	618	23 115(third round only)
	Stockheim	228	677	32 130 do.
	Obersdorf	249	739	120 do.

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corresponding velocity of sound has been used, wind being neglected. It will be seen that in most cases the passage of several pulses past a series of stations can be recognised. The complete explanation of all the receptions is hardly to be hoped for.

Of the records made on 17th July 1928 the most remarkable are those at Königsberg at the great distance of 578 km. The times of arrival of the pulses which travelled with a velocity exceeding that of sound and therefore had negative 'delays' appear to be well established. It can only be supposed that there was a very strong wind favouring the passage of the waves at a moderate height. The most consistent observations to S.W. give a delay of the order 120 sec. whilst those to the N.E. give a delay of about 245 sec. It has been demonstrated in other cases that delays of 120 sec. or so imply that the waves have returned to earth from a height of about 40 km. The delays of 245 sec. may be interpreted as due to the passage of the waves up and down a second time, an intermediate reflection having taken place at the earth. The stations in the N.E. at distances appropriate for recording waves with 120 sec. delay were not effective owing to wind disturbance. It so happened that observations were being made in England on this particular day 17th July 1928 and the delays of the pulses recorded at Birmingham 210 km. from the source were 111, 114 and 116 sec. The agreement with the figures for stations at comparable distances from Jüterbog is remarkable.

The observations made on 19th December 1928 provide a remarkable illustration of the hypothesis that waves can be reflected alternately from an upper layer and from the ground. The delay of a wave in a single journey to the upper layer and back seems to have been about 80 sec. The last wave to reach Königsberg apparently passed up and down five times. The comparatively small delay for the single journey indicates that the reflecting layer was at a moderate height, probably not much above 30 km.

The observations of 26th March 1929 provide an instance of transmission to S.W. and to N.E. with about the same delay. This is evidence that the phenomena of delayed transmission can not be due mainly to wind, for wind could not produce just the same delay in waves travelling in opposite directions.

It is understood that a complete analysis of all these observations has been undertaken by Prof. Hergesell and his collaborators. The results will be of great importance.

4. Observations in England. Observations of the air-waves from gunfire have been made systematically in England since 1927. To the end of 1930 the number of successful trials * was 22. During 1929 and 1930 the firing was nearly always at Woolwich. In summer reception of the waves from this source is always possible at Cefn Mably near Cardiff at a range of 222 km. and frequently possible at Birmingham (174 km), Bristol (187 km.) and Nottingham (183 km.). At all these stations the angles of descent of the waves can, under favourable circumstances, be measured.

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* R.Met.Soc.C.J. (1931) p.331.

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Table 2. Estimates derived from English observations of the Air Waves from Gunfire: Velocity of Transmission and the corresponding Apparent Temperature.

Height in Kilometres	40	45	50	55	40	45	50	55
	Velocity in m./s.				Temperature in °A.			
1928 May 11	338	353	368		285	311	337	
1928 May 23	324	341	357		262	290	318	
1930 June 17	340	354			289	313		
1928 July 4	333	352			277	310		
1929 July 11	350	376	400		306	353	400	
1930 July 11	345	352	359	378	297	309	322	356
1928 July 17	343	358	372	385	293	320	345	370
1930 July 17	339	353	358	363	287	310	320	329
1928 Aug. 2	334	352	368	385	279	309	338	369
1930 Sep. 3	312	333	353		243	277	311	
Means	336	352	367	378	282	310	336	356

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The delay in the passage of the waves has in most cases been about 100 sec. There have however been a few cases in which the delay was much greater. There is however only one instance, Nottingham 7th October 1930, in which the delay was as much as 200 sec. and the reflection of the waves by the ground may have occurred. The delay is generally at its minimum in July.

In cases in which the angles of descent of the air-waves have been measured and the results of balloon soundings up to the stratosphere are available calculations can be made which give the heights attained by the waves and temperatures of the air at such heights can be estimated.

The computed or apparent temperatures at heights from 40 to 55 km. are given for eleven dates in Table 2. The corresponding velocities of the waves are also given. Since the temperature is only used in the calculations as an element proportional to the square of the velocity of sound stress must be laid on the epithet 'apparent temperature'. The velocity may be due in part to wind, though this is unlikely when the delay is the same at Cefn Mably to the west and Nottingham to the north of the source.

The observations are too much concentrated in the summer months for annual variation to be brought out clearly but there is some indication that temperature at 40 km. reaches a maximum in the middle of July. This is the significance of the minimum found at that season of the time of passage of the waves.

It should be noted that the evidence for the very high temperature computed for 11th July 1929 is not strong, it depends on an observation at Birmingham of the large angle of descent, 35°.

5. Balloon Observations. The height attained in soundings with balloons seldom exceeds 20 km. Thus in England in 1927, of 30 ascents exceeding 10 km. 20 reached 16 km. or more and of these 6 exceeded 20 km., the greatest height being 21.9 km. To reach greater heights the balloon must be made of thin rubber which will stand great extension. Large balloons are likely to be more efficient than small ones as the weight of a balloon is proportional to its area, the lifting power to the volume. In 1930 Prof. Wigand obtained five specially made balloons from the Continental Tyre Company and two of these sent up on September 8th and 14th attained heights exceeding 30 km. According to Frankenberger * the most probable value of the maximum height was in each case 33 km. The corresponding temperature was about 226°A. There was a gradual rise of temperature from 20 km. upwards and no indication of abnormality near 30 km. The airwave observations have led us to expect a somewhat rapid increase of temperature from 30 km. upwards but the exact height of the transition is doubtful so that the balloon observations cannot be regarded as contradicting the other evidence. The big balloons which are made of sheet rubber .17 mm. thick and have a diameter of 2.5 metres are expensive. It is intended however that ascents shall be made near Hamburg on days when explosions are to take place so that comparisons of the two methods of exploring the upper atmosphere may be facilitated.

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* E. Frankenberger. Hochfahrten von Registrierballonen Ann.d.H.u.M.M. 59 (1931) 20.

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6. Theory of the Reduction of Observations of Abnormal Audibility.* The ideal which is aimed at in observations of abnormal audibility is to determine the time of passage of the airwaves as a function of the distance; the angle of descent of the waves at any distance can be deduced. Further, if the strength of the wind and the velocity of sound are known for all heights up to a certain level the course of the waves in ascending and descending can be traced up to that level. The range above that level can be computed and can be regarded as a function of the inclination at which that level is crossed. If the assigned level is within the stratosphere it is reasonable to suppose that the velocity of transmission at greater heights increases continuously and if we knew the range for inclinations of the rays from zero upwards we could use the solution of a well known integral equation to compute the velocities. It is however impossible to determine by observation the ranges of rays which pass through the stratosphere at a small inclination to the horizon. All rays which start from the ground have considerable inclinations in the stratosphere. Before the integral equation can be used the ranges of the rays with small inclinations in the stratosphere must be estimated and although the estimates are restricted by a certain condition there is considerable room for choice. Thus it follows that observations can not yield definite information as to the nature of the transition from the region of low velocity in the stratosphere to the region of high velocity above.

The English observations have generally been reduced on the assumption that there is a uniform gradient of temperature in the transitional region. This assumption has been adopted merely as a first approximation. It may be that the assumption of a discontinuity of temperature would be a better approximation to the truth. The point to be emphasized is that the sound-ranging observations can not discriminate between the two assumptions.

The difficulty could be met by the production of an explosion at a height of about 40 kilometres. Work is proceeding in America on the production of the Goddard rocket which is to be able to carry a considerable weight to such a height so the suggestion is not impracticable.

7. Comparison with Gowan's Theory. The effect of ozone on the temperature of the upper atmosphere has been investigated mathematically by E.H. Gowan. Ozone is an effective absorbent of ultraviolet light from the sun and the absorption of this light tends to warm the air. The constituent of the atmosphere most effective in absorbing and emitting heat in the infra-red is water vapour. At levels where there is much ozone the temperature of the air will depend on the balance between the absorption of energy in the ultraviolet by ozone and the emission of energy in the infra-red by water vapour.

On any of the assumptions which Gowan has considered the mass of water vapour between 30 km. and 40 km. is much in excess of the mass of ozone. It is likely in fact that the mass of water vapour between those levels is twice as great as the total mass of ozone in the whole atmosphere. Gowan's calculations indicate that if water vapour were as good a radiator mass for mass under the conditions of the upper atmosphere as near the ground then the temperature at 40 km. would not exceed 240°A; 300°A would be reached at some height between 50 km. and 60 km. These results are not in accordance with the observations of airwaves.

* Cf. Gerlands Beiträge (in the press)

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Gowan has considered however the possibility that the water vapour above 30 km. is inactive as a radiator and on that basis he finds * a steady gradient of temperature from 30 km. upwards and the temperature at 40 km. is 300°A.

It is hardly likely that water vapour is completely inactive at such heights. There is however evidence that the radiating power falls off rapidly with decreasing total pressure. Experiments were carried out by Miss Eva von Bahr in Upsala and published in 1902. The experiments did not cover the wave-lengths which occur in the central part of the spectrum of a body radiating at atmospheric temperature and direct observations of the radiation at such wave lengths is difficult. It is to be hoped that further experiments will be undertaken. Meanwhile as a working hypothesis it might be assumed that the radiating power of water vapour was proportional to the total pressure. Clearly Gowan's tenatative assumption in which the water vapour was neglected entirely should be modified. The modification would introduce a progressively increasing gradient of temperature between 30 and 40 km. in place of the uniform gradient of his diagram. Thus the observations of airwaves suggest problems of considerable interest in pure physics as well as in the study of the atmosphere.

8. The Future. Steps are being taken by Prof.Hergesell as President of the Commission for the Investigation of the Waves from Explosions, a Commission of the International Meteorological Organization, to arrange for explosions of the magnitude of those at Oldebroek and la Courtine, so that observations of audibility can be made over large areas. It is also likely that the Meteorological Association (a section of the International Union for Geodesy and Geophysics) will purchase undographs to be placed at the disposal of investigators who have facilities for observing the waves from explosions such as those which are frequent in certain mining districts. If these programmes are carried out knowledge will be obtained of conditions in the upper atmosphere in all parts of the world and it may be possible before long to establish new "Solar and Terrestrial Relationships".

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* Royal Soc.Proc.A.128 (1930) 543 Fig.4 Curve (1)

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THE EFFECT OF TEMPERATURE UPON THE ULTRAVIOLET ABSORPTION SPECTRUM OF OZONE.

By Oliver R. Wulf and
Eugene H. Melvin,
Bureau of Chemistry and Soils,
Washington, D.C.

Following the plans mentioned last year in a paper on the absorption spectrum of ozone (Proc. Nat. Acad. Sci., 16, 507 (1930)), a study of the effect of temperature upon the ultraviolet absorption has been made. It had been recognized that a triatomic molecule such as ozone, possessing such normal vibration frequencies as are indicated by its infra red spectrum, might show a pronounced effect of temperature in its electronic absorption. The visible spectrum of chlorine is an excellent illustration of this for the case of a diatomic molecule. If such did occur in ozone it would be important, for it might alter somewhat the estimates of the amount of ozone present in the upper atmosphere, and part of the apparent variation in the amount of this ozone might be simply a variation in the temperature of the atmosphere at the height of the ozone layer. It might furthermore lead to a direct method of estimating the temperature at this altitude.

The ultraviolet absorption of ozone consists of a large number of bands appearing against a background of continuous absorption. The effect of temperature upon this absorption has been investigated over the region 3400-2300 Å. The region 3400-2900 Å has been studied from about -78° C to room temperature, while in the region of stronger absorption, i.e., 2550 Å, the absorption has been photographed at as high as 250° C. The former region has, however, been studied in most detail.

A definite influence of temperature has been observed though it is rather small. Grossly it manifests itself as an increase in contrast with decreasing temperature, perceivable with the eye alone on the original plates. The work has been done on two Hilger spectrographs, one the familiar E 2, the other of the Fery design. The continuous spectrum of hydrogen was used as a background, and the absorption of ozone, produced in a silent discharge ozonizer and of a wide variation of concentrations, was photographed in quartz and pyrex cells at the temperature of solid carbon dioxide and at a series of higher temperatures.

A photometric study of the plates has been made against a series of exposures of the same source weakened by calibrated screens. The results of this study at the present time show the increase in contrast to be chiefly a weakening of the absorption between the band edges with decreasing temperature. In the edges of the bands, that is, at the maxima of absorption, the intensity of absorption changes only a little with temperature. From band to band the change in the intensity of absorption remains the same at -78° C and at room temperature, except for a gradual alteration which appears to be due to the continuous background. Thus it appears that all the bands that have been studied come from vibrational states of very low if not the lowest energy. Bands from a vibrational level of as high as 400 cm^{-1} would show a change of a few fold in intensity over this range of temperature and of course much more from a level as high as 1000 cm^{-1} (see reference given above).

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The bands, though somewhat diffuse, tend to degrade to the red. Thus the absorption between two bands is apparently due partially to the rotational structure of the bands lying just to shorter wavelengths, chiefly of course to that of the adjacent band. Partially it appears to be due also to the overlying continuous absorption, and in an amount which increases with decreasing wavelength. The observed change of absorption with temperature can thus be explained as a decrease in the higher rotational absorption of the bands with decreasing temperature, and possibly also a decrease in the absorption of the continuous background.

Certain groups of the bands show a decided tendency toward regular spacing. Also several discontinuities have been observed in the intensity change from band to band within such groups. These two facts have permitted making a partial vibrational analysis of the bands which indicates two active vibrational degrees of freedom in the excited electronic state.

This influence of temperature upon the ozone spectrum may affect somewhat the estimation of the amount of ozone in the upper atmosphere, which depends upon the values of absorption coefficients measured in the laboratory. While the effect is not large, it may be of importance especially in the method of estimation which uses the difference in intensity of solar radiation at two wavelengths at one time. The effect would be greatest if these wavelengths happened to be located one in a band edge and the other well in a minimum of absorption between bands. The measurements indicate at present that this might be as great as a variation of ten per cent in the ratio of log I_1/I_2 for the range from room temperature down to -78° C. If such a variation in temperature occurs in the ozone layer this effect could account for a part of the apparent variations in the amount of ozone from day to day. It might also account in part for any differences found to exist in the values determined for a series of wavelengths on any one day from a number of photographs. Depending of course upon the actual variations in temperature of the upper atmosphere the effect might be correspondingly greater or less than that estimated above for a temperature range of 100° in the neighbourhood of 0° C.

It should be pointed out particularly that only the temperature effect has been considered here and that if there is also an effect of pressure upon the absorption this would further complicate the matter.

In conclusion, it does not seem hopeless to attempt to obtain some idea of the temperature of the atmospheric ozone from a study of the intensity distribution in the ozone bands at the edge of the solar spectrum. The change in contrast shows sufficiently on the laboratory plates to judge, for example, whether the ozone used in a particular exposure was at a temperature considerably below zero centigrade or considerably above. Thus, unless the presence of the Fraunhofer lines and some further factor such as a pressure effect complicates the procedure too much, it should be possible to gain a rough idea of the temperature at the height of the ozone layer from a careful comparison of the ozone bands on solar plates with those taken under known conditions of temperature in the laboratory.

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QUATRIÈME RAPPORT AU CONSEIL INTERNATIONAL DES UNIONS SCIENTIFIQUES.

Introduction.

Avant de commencer ce quatrième Rapport de notre Commission nous avons le douloureux devoir d'évoquer la mémoire de trois de ses membres les plus éminents, décédés depuis 1932 : le Général FERRIÉ, le Dr. L. A. BAUER, le Dr. Ch. E. ST. JOHN. De nombreux articles (1) ont été déjà consacrés à retracer leur activité et leurs mérites scientifiques, mais nous voulons rappeler ici plus spécialement la part très grande qu'ils ont prise à l'œuvre que nous poursuivons en commun. Le Général FERRIÉ faisait partie de la Commission pour l'étude des relations entre les phénomènes solaires et terrestres depuis sa fondation (1924) comme répresentant de l'Union radio-scientifique internationale et avait été nommé en 1931, premier Vice-président du Conseil international des Unions scientifiques. Dès 1909, ainsi que le rappelle CH. FABRY, les transmissions radio avaient fait la conquête du monde et les lois qui les régissent tendaient à prendre une signification cosmique. FERRIÉ parmi les premiers, comprit cette évolution et s'attacha à la favoriser en organisant d'abord

(1) P. BRENOT, *Le Général Gustave Ferrié* (1868-1932), « Bullet. géodésique », nr. *33*, 1932, p. 35. — CH. FABRY, *Gustave Ferrié*, « Bullet. Soc. Astr. de France », *46*, 1932, p. 198. — J. A. FLEMING, *L. A. Bauer* (1865-1932), « Science », *75*, 1932, p. 452. — *Bauer Memorial Number*, « Terrestr. Magnet. and Atmosph. Electricity », sept. 1932. — H. D. BABCOCK, *Ch. E. St. John*, « Publ. Astr. Soc. of the Pacific », *47*, 1935, p. 115. — C. G. ABBOT, *Ch. E. St. John*, « The Astrophys. Journ. », *82*, 1935, p. 273.

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les « signaux horaires », puis la détermination mondiale des longitudes, opération d'une importance fondamentale pour les astronomes, géologues, géographes etc., et qui est maintenant en plein développement. Le Général FERRIÉ avait toujours témoigné le plus vif intérêt pour l'activité particulière de notre Commission et avait contribué directement au premier et deuxième rapport avec deux notes, la deuxième en collaboration avec JOUAST, où il exposait avec sa précision et sa clarté habituelles, le problème de la dépendance des transmissions radio de la lumière et de l'activité solaire. Il y notait déjà les différences d'allure des ondes longues et des ondes courtes ainsi que les relations entre les variations du magnétisme terrestre (qui dépendent elles-mêmes pour la plus grande partie des phénomènes solaires) et les anomalies de propagation des ondes herziennes.

Nous sommes redevables à L. A. BAUER de mesures magnétiques sur tout le globe et de la fondation du journal international *Terrestrial Magnetism and Atmospheric Electricity*. Il s'intéressa surtout à l'étude des relations de l'électricité atmosphérique avec le magnétisme terrestre et l'activité solaire, question liée aux variations rapides du champ terrestre plutôt qu'à ses caractères permanents. Les remarquables exposés qu'il fit sur ce sujet contribuèrent à augmenter les connaissances que nous en avons.

BAUER organisa aussi les observations magnétiques à effectuer au cours des éclipses solaires pour onze expéditions, à partir de celle du 28 mai 1900 ; il fit lui-même des nombreuses observations et constata avec certitude un effet magnétique en liaison directe avec le phénomène de l'éclipse. Il fournit une importante contribution personnelle au premier Rapport de notre Commission par une note relative aux mesures de l'activité solaire ; auparavant, il avait déjà signalé que « a quantity indicative of the amount of variability of sunspottedness during a given period was in general the most successful measure of solar activity, adopting for this the average departure D per month, namely the average difference, regardless of sign, between the daily sunspot numbers and the monthly mean sunspot number ». La corrélation entre la quantité D et l'activité magnétique terrestre se montra tout de suite plus grande que les autres, probablement, comme le fait remarquer BAUER, à cause des « invisible suns-

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pots areas which, when they become visible to us, are no longer active in the sense of emitting radiations and emanations which effect the earth's magnetic and electric fields ». L. A. BAUER fut nommé membre de ce Comité en 1929 par l'Union géodésique et géophysique.

CH. E. ST. JOHN est mort le 26 avril 1935 à Pasadena, California, près de l'Observatoire de Mont Wilson, où, pendant de longues années, il exerça sa féconde et très remarquable activité dans le domaine de la physique solaire. De 1909 à 1932 les mémoires si nombreux qu'il fit paraître dans les *Contributions from the Mount Wilson Observatory*, et les *Proceedings of the National Academy of Sciences* exposent les résultats de ses observations, notamment sur les tourbillons solaires, les mouvements radiaux dans les taches et les courants convectifs dans l'atmosphère de l'astre, sur l'effet Einstein relatif au déplacement des raies dans la photosphère et sur la rotation solaire. Sur celle-ci en particulier, les observations systématiques faites à Mont Wilson lui laissèrent entrevoir une variation possible dans la vitesse de rotation du soleil ; il écrivit sur ce sujet une note très importante dans le troisième Rapport de notre Commission. Bien que ce problème n'est pas directement lié avec les relations entre les phénomènes solaires et terrestres, il peut, cependant, s'y rattacher indirectement par la présence dans la photosphère et cromosphère des courants périodiques, qui en sont la conséquence, et que ST. JOHN a cherché à mettre en évidence par différentes méthodes.

Son intérêt pour la coopération internationale, soit comme Président de la Commission de physique solaire de l' Union astronomique internationale, soit comme membre de cette Commission même, a toujours été actif et efficace. Ses relations aux différents congrès de l'Union, auxquels il ne manqua jamais d'assister, en sont le plus sûr témoignage. Quelques mois avant sa mort, quand il sentit ses forces décliner, un des soucis de cet esprit généreux fut d'assurer sa succession à la présidence de la Commission 12 de l'Union astronomique internationale, afin que les travaux ne fussent point interrompus.

En vertu des décisions du Conseil international des Unions scientifiques (Deuxième assemblée générale, Bruxelles, juil-

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let 1934 [1]) MM. D'AZAMBUJA et NICHOLSON étant nommés représentants de l'Union astronomique internationale, notre Commission est actuellement composée comme suit : C. G. ABBOT ; G. ABETTI, Président ; E. V. APPLETON ; L. D'AZAMBUJA ; W. BRUNNER ; S. CHAPMAN ; H. DESLANDRES ; CH. FABRY ; J. A. FLEMING ; S. B. NICHOLSON ; G. C. SIMPSON ; C. STÖRMER.

Depuis la publication de son troisième Rapport, l'activité de notre Commission s'est manifestée dans plusieurs circonstances parmi lesquelles nous citerons les suivantes.

A la quatrième assemblée générale de l'Union astronomique internationale (Cambridge Mass., septembre 1932) les membres présents de notre Commission ont rédigé un rapport qui a été publié dans les *Transactions of the Union* (2).

Au cours de la cinquième assemblée générale de l'Union astronomique à Paris (juillet 1935), les membres de notre Commission qui assistaient à ces Congrès, tinrent avec la Commission 11 (Phénomènes chromosphériques), une réunion mixte où furent discutées différentes questions, en particulier, celle de coordonner et de publier les observations des phénomènes solaires susceptibles d'être rapprochés des phénomènes terrestres.

A l'assemblée générale de l'Union radio-scientifique internationale (Londres, septembre 1934) on s'est particulièrement occupé du problème de l'influence des phénomènes cosmiques, et les solaires surtout, sur la propagation des ondes herziennes. A cet effet, on a recommandé et organisé la collaboration internationale dans le champ des études et des expériences qui se rapportent à la ionosphère. Parmi les nombreuses résolutions adoptées au cours de cette assemblée on a décidé notamment : de continuer les observations des phénomènes solaires en relation avec les radio-transmissions, de preparer les cartes du parcours optique corpusculaire pour les futures éclipses, d'organiser et d'unifier les observations spéciales qui seront faites pendant ces mêmes éclipses. D'autre part, étant données les relations qu'on a

(1) SIR HENRY LYONS, « Rep. of Proceed. Second Gen. Ass. of the Intern. Council Scient. Unions at Brussel's » London, 1935, p. 15.

(2) Vol. IV, Cambridge, 1933, p. 255.

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remarquées entre l'activité magnétique et certaines anomalies dans la propagation des ondes radio-électriques, il serait très utile que l'on mesurât l'activité magnétique pendant des périodes plus courtes que la journée solaire. Il serait de même assez nécessaire d'organiser des études plus approfondies du problème des perturbations électriques d'origine, en apparence, ultra-terrestre, les observations étant faites dans un grand nombre de points différents des deux emisphères et sur une gamme très étendue de fréquences, en particulier sur fréquences élevées.

Pour la deuxième assemblée générale du Conseil international des Unions scientifiques (Bruxelles, juillet 1934) j'ai, après avoir consulté les membres de notre Commission, rédigé un Rapport qui a été présenté par le Prof. CHAPMAN (1). La publication de ce quatrième Rapport a été décidée par la dite assemblée ; il est complété, comme les trois précédents, par des notes originales des membres de la Commission et de savants qui s'intéressent aux recherches de physique solaire ou terrestre, dans les relations que ces sciences peuvent avoir entre elles. Enfin, nous avons cherché à résumer les résultats obtenus depuis trois ans dans cet ordre d'études.

Discussion sur les relations solaires et terrestres.

Sous la présidence de H. F. NEWALL, le 27 octobre 1933, une intéressante discussion, que nous croyons utile de reproduire ici a eu lieu au siège de la *Royal Astronomical Society*, sur le problème des relations entre les phénomènes solaires et terrestres (2).

« Prof. CHAPMAN opened the discussion by recalling the summary of the present state of knowledge of solar and terrestrial relationships which was given by the International Research Council's Committee on that subject, in their First Report, published in 1926. He distinguished between the daily and seasonal relationships (perhaps most important of all, but generally tacitly ignored in these discus-

(1) SIR HENRY LYONS, l. c. Annexe IV, p. 123.
(2) « The Observatory », *56*, 1933, p. 367.

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sions), due mainly to the changes of the earth's orientation relative to the sun — or, what is equivalent, to changes in the sun's geocentric position — and those relationships due either to intrinsic changes on the sun, or to changes of orientation of the sun relative to the earth; the latter may also be regarded as changes in the earth's heliocentric position. Seasonal variations may arise from either the geocentric or the heliocentric changes, and it is still uncertain which play the larger part in the annual variation of magnetic activity».

«He proceeded to describe the main relationships between the sun and terrestrial magnetism, as disclosed by the researches of SABINE, MAUNDER, CHREE, MAURAIN, BARTELS and others. The close correlation between the annual mean sunspot data and various annual mean magnetic characteristics indicated a terrestrial relationship with intrinsic changes on the sun; the influence of the sun's orientation is shown mainly by the 27-day recurrence tendency in magnetic activity. There is evidence of close association between intense magnetic storms and the central passage of great sunspots two or three days previous; but there is also a marked lack of detailed correspondence between the sequence of disturbed conditions on the sun's surface and the course of terrestrial magnetic activity. The terrestrial data seem to imply solar changes which solar physicists have not yet been able to discern».

«The magnetic variations are closely associated with changes in the ionization of the upper atmosphere; radio measurements now afford most valuable indipendent information as to these changes. The ionization is thought to be due partly to charged corpuscles from the sun, which affect the polar regions most intensely, and partly to ultra-violet radiation and, probably, neutral solar particles, the two latter being responsible for the daily re-ionization of the sunlit hemisphere. It is extremely difficult to gain more direct knowledge of the two corpuscular radiations, but it may be possible to detect the presence and speed of the stream of corpuscles, when lying between the earth and sun, by the spectral lines which its absorption of sunlight should produce. Radio measurements of the ionization of the upper atmosphere during a solar eclipse also throw rather direct light upon the nature of the solar ionizing agent and indicate that ultra-violet light is one of the main agents».

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« Unfortunately, despite the striking solar relationships with terrestrial magnetism, which render this the most promising field of investigation into solar and terrestrial connections, the way in which the various magnetic changes are produced is still very obscure ».

« Dr. G. M. Dobson stated that the experimental data afforded no evidence of a correlation between the amount of ozone in the upper atmosphere and the sunspot numbers, but that there seemed to be a small correlation between magnetic activity and the amount of ozone present, the evidence for which however, is not very reliable. Recent observations on the height of the ozone layer have used scattered light from the zenith blue sky rather than direct sunlight. The height of the ozone layer averages about 20 km. When ozone is particularly plentiful, the additional ozone is found at a height of about 15 km ».

« Dr. C. E. P. Brooks recalled that investigations, such as that of Köppen, show that there is a « reversed » relationship between sunspots and terrestrial temperatures, amounting in the tropics to nearly half a degree : greater sunspot area is correlated with lowering of temperature. Rainfall observations are very seriously affected by local conditions, and averages for large regions have only been found for a few countries. Schostakowitsch found that the average rainfall in Russia and also in Siberia was greater in times of sunspot maximum. For Lake Victoria, where lake level was taken as the criterion of original rainfall, the correlation coefficient is about 0.8 ».

« The average number of thunderstorms each year at a number of stations in Central Siberia had shown a 0.88 correlation with sunspot numbers. Dr. Brooks was at the moment engaged on a study of this relationship for other areas, and the correlations are definite, if not so striking. The correlation coefficient for the United States is + 0.28, decreasing steadily from + 0.36 in the south-eastern group to + 0.08 in the western inland group. The data for Suva and Apia show mutual agreement, and when combined give a coefficient + 0.49. The Baltic coasts and inland districts of Sweden both give positive correlations with sunspots, but only that for the inland regions is at all significant ».

« Mr. R. A. Watson Watt said that three types of radiote-

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legraphic phenomena had in recent years been relied on to throw some light on solar and terrestrial relationships. These were atmospherics, wireless echoes of short delay (order of milliseconds), including fading phenomena and wireless echoes of long delay (order of tens of seconds) ». DE GROOT had suggested a « cosmic » origin in explanation of this data on atmospherics, SCHINDELHAUER had more recently ascribed them to changes in the circulating currents of the ionosphere and found support for his hypothesis in special relations between mean direction of arrival of atmospherics and the magnetic meridian, and in a 27-day recurrence-tendency in atmospheric intensity. Mr. WATSON WATT felt that this support was invalid, the relation to the meridian being largely due to an arbitrary resolution of an ambiguity in the direction of arrival, the 27-day recurrence-tendency to the changes in ease of propagation resulting from a 27-day recurrence-tendency in the ionisation at the base of the ionosphere. While this latter phenomenon left some little doubt in the true interpretation of atmospheric data, he was strongly of opinion that the British observations on atmospherics indicated a real 27-day recurrence-tendency in European thunderstorm activity.

On wireless echoes of short delay he would only outline the structure of the ionosphere as inferred from radio soundings, but would add the remark that there was no valid reason for expecting a simple structure (*e. g.* a single-layer structure) to emerge from the impact, on a mixed atmosphere of ionisable gases, of a wide spectrum of ultra-violet light and a wide velocity spectrum of particles. He had given an example recently of the more intimate fine structure of the *E* region, showing the return of echoes from equivalent heights of 97,110,112, and 122 km., for a single radio frequency, within a period of a few minutes, return from each of these well-marked heights recurring intermittently. He indicated how, from the relative flatness of the main run of the curve relating equivalent-height to frequency, by extrapolation to zero-frequency, and by simple integration under the curve, it could be shown that the « equivalent » heights inferred could not, in normal cases, differ very widely from the true geometric heights from which the wireless echoes were returned.

The wireless echoes of long delay presented extreme difficulties in interpretation. STÖRMER'S use of them as evidence

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for his toroidal electron surface at a great distance from the earth left the need for some focussing action to counterbalance mere inverse-square spreading and the quality of optical « figuring » thus demanded was difficult to concede in view of the probable velocity spectrum of the electrons. On the other hand the hypothesis that these echoes had lived their delay-time in the ionosphere presented grave difficulties of attenuation ; APPLETON had shown that at least the main trajectory must have lain above 400 km. to avoid prohibitive losses by collisional friction. There was urgent need for more experimental evidence in all the three types of phenomena discussed ; particularly in the case of long-delay echoes was additional evidence, from more stringent experimental methods, required.

Dr. F. J. W. WHIPPLE said that he knew of two investigations of the influence of solar changes on atmospheric electricity. BAUER had announced at one time that there was a correlation between annual means of atmospheric potential gradient and of sunspot numbers, but this generalization had not been confirmed by subsequent events. Mr. A. W. LEE had looked for a connection between the variability of potential gradient during a day and the magnetic character of the day. The relation which he thought he had discovered in the Lerwick and Kew statistics was not very close, and the line of investigation had not been followed up.

Solar influence was manifest in every phenomenon with a regular diurnal variation. The latest evidence for such variation was found in the Kew Observatory records of the electric discharge from a needle point 10 m. above the ground. The discharge has a pronounced maximum in the afternoon.

The solar influence on the temperature of the atmosphere at heights of about 40 km., the heights from which the airwaves from explosions return to earth, had not yet been investigated fully. Apparently the temperature is highest in July, the most favourable month for receiving the airwaves.

Prof. H. F. NEWALL summarised the progress that had been made with this question along different lines, and referred in particular to the orientation of the aurora. He mentioned that HALE hand recently been working anew on the general solar magnetic field.

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Année polaire.

L'organisation de l'année polaire internationale 1932-33, les buts que l'on s'était proposé d'atteindre au cours de cette campagne, les méthodes de travail adoptées et une partie des résultats obtenus, ont été exposés à la deuxième assemblée générale du Conseil international des Unions scientifiques (juillet 1934) par D. La Cour (1). Dans son rapport, on trouve des renseignements qui intéressent particulièrement notre travail. L'année polaire se caractérise par le fait que des recherches ont été effectuées, non seulement dans les régions polaires, mais aussi sous toutes les autres latitudes, conférant ainsi à cette expédition une signification mondiale plutôt que polaire. Le choix des stations dans les régions arctiques n'avait pas pour but d'étudier les phénomènes de ces régions en particulier, mais devait permettre de préciser leur rôle dans le concert des phénomènes mondiaux. Cette dernière étude est spécialement importante pour la recherche des relations entre les phénomènes solaires et terrestres.

Les aurores polaires ont été observées principalement pour déterminer la position qu'elles occupent dans l'espace, leur étendue sur le globe et leurs relations avec les couches conductrices de la haute atmosphère ; cependant, cette étude devait aussi renseigner sur la dépendance des aurores à l'égard des phénomènes solaires, et sur leurs rapports avec le magnétisme terrestre, le rayonnement cosmique et la propagation des ondes herziennes.

Pendant cette année polaire, on s'est servi pour la première fois d'un grand nombre de petits spectroscopes spécialement destinés à constater, malgré les nuages, la présence et la dispersion des aurores sur le globe.

D'autre part, on a étudié les perturbations magnétiques périodiques et non périodiques, leur distribution, leur propagation et leur dépendance des phénomènes solaires ; on s'est efforcé aussi de préciser les caractères des orages magnétiques et leur début brusque sur toute la terre. De plus

(1) G. Perrier « Bullet. géodésique », nr. *43*, 1934, p. 127.

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afin d'étudier, de manière rationnelle la propagation des ondes radioélectriques, on a organisé des émissions régulières sur diverses longueurs d'onde ; ces émissions étaient faites par des stations situées à des longitudes très différentes et réparties sur l'année et sur les jours internationaux pour permettre de serrer de plus près le problème de la marche annuelle, aussi bien que celui de la marche diurne de la propagation des ondes de differentes longueurs.

Un autre résultat de l'année polaire a été la création en Afrique de quatre observatoires magnétiques, alors qu'il n'en existait qu'un seul auparavant, et une amélioration des réseaux de stations géophysiques.

Signalons en outre le rapport de CH. MAURAIN sur l'organisation générale et les travaux scientifiques de l'année polaire 1932-33 (1) ; il y relate plus spécialement ce qui concerne la participation française et les observations au Scoresby-Sund de A. DAUVILLIER : ces travaux seront mentionnés dans les arguments particuliers qu'il a traité. Il suffira de mentionner ici un article (2) dans lequel il résume les problèmes actuels de la physique cosmique et où il cherche à interpréter, à la lumière des théories modernes, les phénomènes de la haute atmosphère en relation avec l'activité solaire.

Phénomènes solaires. — Cycles. — Rayonnement solaire.

En vertu d'une décision du Conseil international des Unions scientifiques, le *Bulletin for character figures of solar phenomena* continuera à paraître régulièrement comme les années précédentes. Le Prof. BRUNNER a publié le deuxième volume de ce Bulletin pour les années 1917-22 ; nous avons ainsi une série complète de 1917 à 1934 avec deux maxima et deux minima. Depuis le mois d'avril 1934, le Bulletin donne aussi la liste des éruptions brillantes d'hydrogène observées au spectrohélioscope.

L'organisation des observations avec les spectrohélioscope a fait l'objet d'une note spéciale de L. D'AZAMBUJA (p. 50).

(1) « Annuaire du Bureau des Longitudes », 1935, p. B 1.
(2) « Revue Scientifique », *73*, février 1935, p. 73.

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Le nombre des stations qui participent à l'observation des protubérances au bord solaire, centralisées à Arcetri s'est sensiblement augmenté grâce à la coopération de plusieurs établissements situés en Tchécoslovaquie, en Russie asiatique et européenne, au Japon. De cette manière, les *Immagini spettroscopiche del bordo solare* (1) publiées sous le auspices de l'Union astronomique internationale, seront de plus en plus complètes. Remarquons que ce genre d'observations à donné des résultats intéressants qu'aucun autre relevé n'avait encore permis d'atteindre (2) et qui pourront faciliter l'interprétation des relations entre les phénomènes solaires et terrestres.

Des rapports de G. E. HALE, J. BARTELS et G. DA COSTA LOBO insérés dans les *Comptes Rendus* de Lisbonne de l'Assemblée de l'Union géodésique et géophysique internationale donnent des indications sur l'organisation et l'importance des observations avec le spectrohélioscope et, en général, sur les différentes méthodes susceptibles d'être appliquées à l'étude et à la mesure de l'activité solaire (3). BARTELS, utilisant les travaux de BRUNNER, constate que, pour les observations de 1912 à 1930, les protubérances au bord, ne conduisent pas à un résultat meilleur que les taches, en ce qui concerne la corrélation avec l'activité magnétique terrestre.

Les recherches très remarquables de B. LYOT sur le spectre de la couronne solaire observée en dehors des éclipses, pourront être utiles à l'étude de l'influence possible des variations de la couronne sur les phénomènes terrestres. En 1934, LYOT, signale (4) que la raie verte a, autour du disque, une répartition très différente de celle qu'elle avait en 1931. Les jets, plus nombreux, se trouvent à des latitudes beaucoup plus élevées alors qu'à l'équateur, la raie verte est souvent invisible. La raie rouge se comporte en général très différemment. Si, par la suite, il est possible d'organiser des observations régulières de ce genre, il serait intéressant de rechercher s'il

(1) Appendici ai fascicoli delle « Osservazioni e Memorie del R. Osservatorio Astrofisico di Arcetri », 1926-1935.

(2) V. par exemple : G. BOCCHINO, *Migrazione delle protuberanze durante il ciclo undecennale dell'attività solare*, « Osservazioni e Memorie del R. Osserv. di Arcetri », fasc. *51*, 1933, p. 5.

(3) CH. MAURAIN et D. LA COUR, Bulletin nr. *9*, 17 au 25 sept. 1933, Copenhague, 1934.

(4) Comptes Rendus, Ac. Sc., *200*, Paris 1935, p. 219.

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n'existe pas une relation entre ces variations et les autres phénomènes solaires, tels que le déplacement de protubérances en latitude.

D'après les travaux de LOCKYER, et plus récemment ceux de H. LUDENDORFF (1) les résultats des observations faites pendant les éclipses semblent indiquer que la forme de la couronne dépend plutôt de protubérances que des taches, sans qu'il soit possible pour le moment, d'affirmer que la couronne a des variations rapides comme les autres phénomènes solaires, ou, au contraire, qu'elle ne change que lentement.

De nouvelles propriétés de la courbe de fréquence des taches solaires pour les cycles successifs ont été mises récemment en évidence par M. WALDMEIER (2). D'après ses recherches la variabilité de la dite courbe aurait origine, non d'une superposition de cycles de durée différente, mais à la superposition d'éruptions successives. Partant de cette hypothèse il conclut, d'accord avec les faits observés, que l'aire limitée par la courbe des taches, l'axe des abscisses, l'ordonnée d'un minimum et celle du maximum suivant, est constante, alors que l'aire comprise entre un maximum et le minimum suivant est proportionnelle à la hauteur du maximum. Il constate enfin que le rapport de la durée de croissance de l'activité à celle de la décroissance augmente quand l'intensité du maximum diminue.

Les conditions de l'éclipse corpusculaire du 19 juin 1936 ont été calculées par A. MICHAILOV (3) pour les trois différentes vitesses des corpuscules : 800, 1600, 3200, km./sec. Il est probable que de nombreuses observations seront faites à cette occasion (p. 57).

Dans un important Rapport *Solar and weather studies*, C. G. ABBOT (4) fait une revue générale des recherches commencées par LANGLEY, et poursuivies par lui-même sur le rayonnement solaire. Elles ont conduit à une ample et très complète organisation dont le but est de mettre en évidence les variations possibles de ce rayonnement et surtout les

(1) « Sitzber. Preuss. Ak. Wiss. Phys. Math. Klasse », 1934, *XVI*. Berlin, 1934.
(2) « Astron. Mitt. », nr. *133*, Zürich 1935, p. 105.
(3) « Bullet. Comm. Recherches du Soleil », *XIV*, Acad. de Sciences de l' U. R. S. S., 1935.
(4) « Smithsonian Miscell. Collect. », *94*, Washington 1935, nr. 10.

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conséquences qui peuvent en résulter sur la terre au point de vue météorologique.

Les valeurs de la constante solaire, déterminées de 1920 à 1934 dans les stations de la *Smithsonian Institution* (Calama et Montezuma au Chili, Mont Harqua Hala et Table Mountain aux Etats-Unis et Mont Brukkaros, en Afrique australe) sont en très bon accord, et présentent pendant cette période une variation maxima d'à peu près, 0.05 g.cal., supérieur à l'erreur moyenne qu'on peut évaluer à ± 0.02. ABBOT en déduit que la constante solaire présente des variations en rapport avec le cycle de l'activité solaire auxquelles se superposent d'autres variations à courte période.

E. PETTIT (1) donne des nouvelles des mesures exécutées à Mont Wilson sur le rapport de l'intensité de la lumière solaire à λ 0.32 μ à celle à λ 0.50 μ avec son radiomètre ultra-violet thermoélectrique. En ce qui concerne la variation du rayonnement ultra-violet, en corrélation avec l'activité solaire, après onze ans, depuis le commencement de ces observations, PETTIT en déduit la conclusion suivante : « Whether there is any evidence of a connection between the ultra-violet and sunspot-curves will probably depend on the events of the next cycle. Possibly the major variations in the ultra-violet curve are due in part, at least, to atmospheric ozone which is somewhat effective at λ 0.32 μ ».

Conditions magnétiques de la terre et courants terrestres.

Au cours d'une récente étude, W. BRUNNER (2) signale que la corrélation entre les nombres relatifs des taches R et les nombres u calculés par BARTELS pour caractériser l'activité magnétique terrestre dépend de la phase du cycle undécennal. L'étude porte sur l'intervalle 1835-1931 et indique que le facteur de corrélation r pour les nombres relatifs annuels des taches et les nombres u de l'activité magnétique terrestre varie régulièrement pendant le cycle de 11 ans (fig. 1) : lorsque

(1) « Trans. Americ. Geophys. Union Sixteenth Ann. Meet. », Part I, Washington (1935), p. 37.

(2) « Astron. Mitt. », nr. *133*, Zürich 1935, p. 131.

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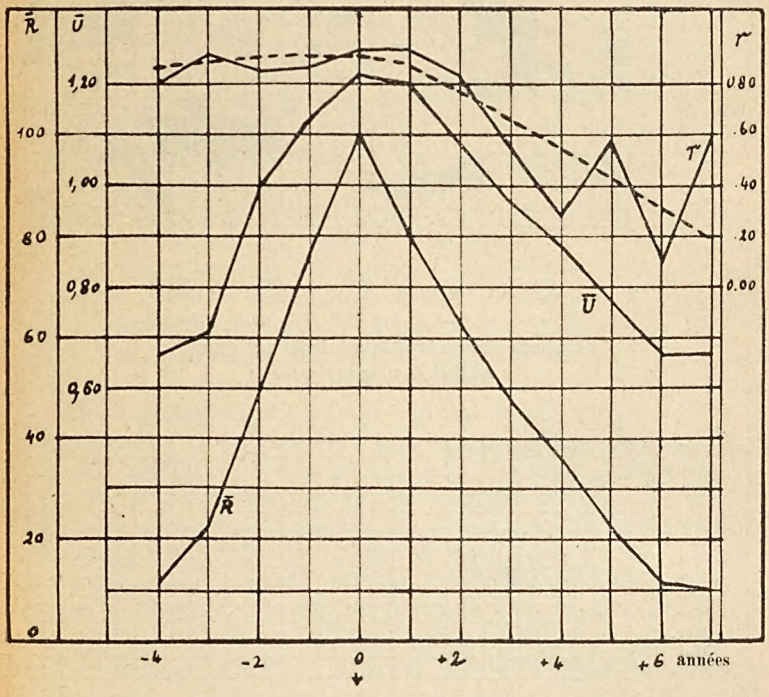
l'activité solaire croît et autour de son maximum, le facteur de corrélation est élevé et presque constant, de l'ordre de 0.90, avec une faible erreur moyenne ; il diminue rapidement



Année de maximum.

Fig. 1.

quand on se rapproche du minimum avec une sensible dispersion, et l'erreur moyenne devient forte.

Ce résultat renforce le fait connu que l'apparition des taches et des facules, n'est pas la cause directe des perturbations magnétiques mais qu'elle réside plutôt dans d'autres phénomènes inconnus, dont dépendraient les taches et les facules elles-mêmes. Les observations systématiques et continues avec le spectrohélioscope (p. 50) donneront peut-être

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quelque indication à ce sujet. Comme l'indique BRUNNER, si la corrélation entre les taches et l'activité magnétique ter-

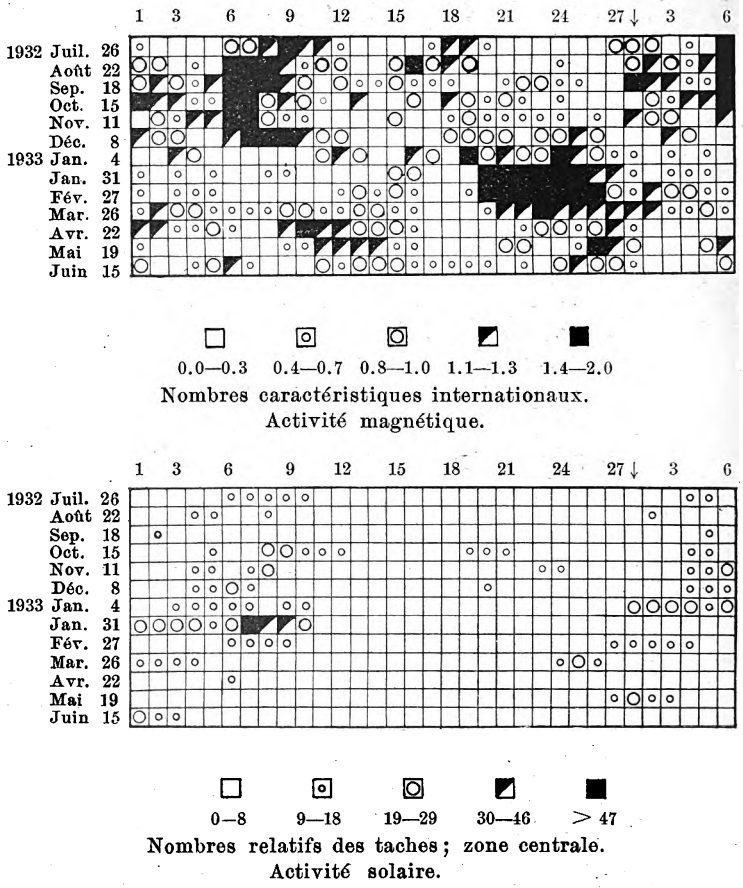

Fig. 2. — Récurrences de 27 jours dans l'activité magnétique et l'activité solaire (juillet 1932-juin 1933).

restre dépend de la phase du cycle undécennal, on devra observer plus de flocculi éruptifs d'hydrogène brillants et de filaments sombres autour des taches pendant la phase

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ascendante et au moment du maximum de la courbe d'activité que pendant la phase descendante et au moment du minimum.

L'action connue de la rotation solaire sur l'activité magnétique de la terre a de nouveau été signalée par J. BARTELS. Un diagramme, dressé par l'auteur, met en évidence une récurrence de 27 jours dans les nombres caractéristiques magnétiques internationaux *C* pour les années 1906-1931 (1). BARTELS a, plus récemment, complété ce premier diagramme par un second, se rapportant au cycle solaire 1923-1933 (2), et dans lequel il compare l'activité magnétique terrestre à l'activité solaire. Le premier travail tient compte des résultats obtenus par la deuxième année polaire commencée le 1er août 1932, et le second reproduit les nombres relatifs des taches limités à la zone centrale du disque solaire c'est-à-dire à un cercle dont le diamètre est égal à la moitié du diamètre du disque solaire. Le diagramme souligne la longueur exceptionnelle des séquences à la fin du cycle undécennal, depuis 1929 environ et montre, entre 1930 et 1933, encore le fait que des régions magnétiquement très actives pendant longtemps sur la terre persistent même si sur le soleil il n'y a aucune tache, ou, ce qui revient au même, qu'à des nombres relatifs de taches faibles ou nuls correspondent au point de vue géophysique, des degrés différents de l'activité solaire.

Signalons le rapport de CHAPMAN (p. 58), au sujet de l'action d'une éclipse solaire sur le champ magnétique terrestre et celui de GÖTZ (p. 118) qui propose d'étudier l'emission du ciel, pendant la journée à l'aide d'un spectrographe au quarz très lumineux pour rechercher l'existence d'une couronne terrestre éventuelle qui se formerait pendant le jour (3).

Enfin CH. MAURAIN (4) rend compte des résultats obtenus pendant l'année polaire 1932-33 sur la variation diurne et sur les perturbations du magnétisme terrestre enregistrées au Scoresby-Sund.

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(1) « Terr. Magn. », *37*, 1932, p. 1.

(2) « Terr. Magn. », *39*, 1934, p. 201. Une petite partie de ce second diagramme est reproduite comme exemple typique dans la fig. 2 (pag. 20).

(3) « Vierteljaschr. Astr. Gesell. », *70*, 1935, p. 343.

(4) « Annuaire du Bureau des Longitudes », Paris, 1935, B. 1.

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Aurores Polaires.

Des très rémarquables recherches ont été poursuivies sur les aurores polaires.

Au Scoresby-Sund pendant l'année polaire A. DAUVILLIER (1) a organisé une veille continue pour les observations

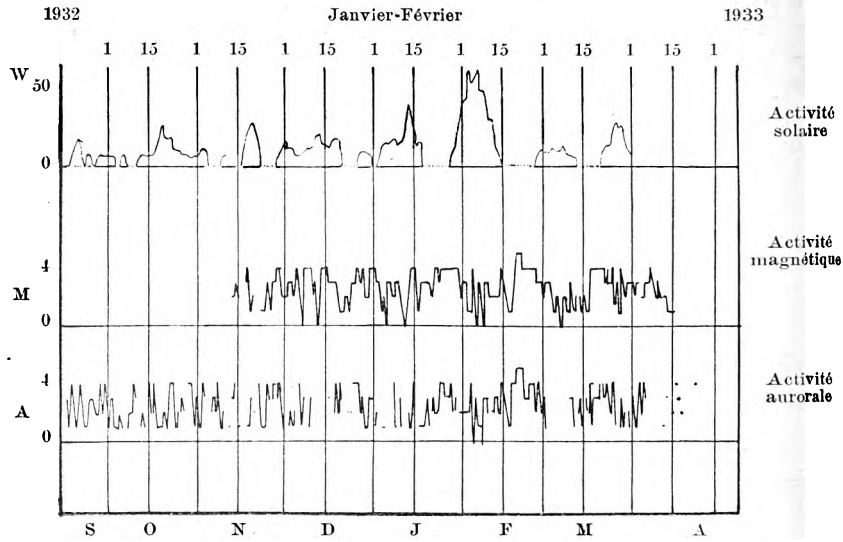

Fig. 3. — Variations d'activité solaire, magnétique, aurorale, de Septembre 1932 à Avril 1933.

des aurores grâce à laquelle il est parvenu à dresser une statistique aurorale complète. Parmi les autres résultats il définit une « activité aurorale » bi-diurne et étudie ses variations au cours de l' « année aurorale ». La courbe déduite de ces observations montre que l'aurore a été un phénomène quasi-permanent au Scoresby-Sund, en un lieu intérieur à la zone

(1) « Journ. de Physique », ser. VII, vol. V, août 1934, p. 398.

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aurorale. Les courbes aurorales et magnétiques qui accusent la période de rotation solaire de 27 jours, sont en opposition de phase avec la courbe représentant l'activité solaire, le décalage étant égal à une demi-période de rotation (fig. 3). DAUVILLIER pense que ce fait peut s'expliquer par la théorie électronique des jets coronaux et leur déviation magnétique au voisinage du soleil ; cependant, si on examine les diagrammes déjà cités de BARTELS (1) il est plus probable qu'on doit attribuer les aurores observées dans cette période de temps (janvier, février, mars 1933) à ces régions solaires dites *M* (p. 61) qui ne présentent guère des phénomènes observables, plutôt qu'à la fréquence des taches.

DAUVILLIER a montré aussi que la variation annuelle de l'activité aurorale est faible ; un enregistreur photoélectrique a, par contre, permis de reconnaître que l'intensité lumineuse de l'aurore pouvait varier dans de grandes proportions.

Propagation des ondes radioélectriques.

L'effet des éclipses solaires sur la ionisation des hautes couches de l'atmosphère et les nombreuses observations faites à ce propos pendant les éclipses de 1932 à 1933 sont décrites en détail dans le rapport de S. CHAPMAN (p. 57). Ainsi qu'il a été dit plus haut, les données relatives à l'éclipse de juin 1936 ont déjà été établies.

Parmi les recherches en cours sur la propagation des ondes herziennes et ses relations avec les phénomènes solaires, citons la série de mesures faites par H. T. STETSON à l'Observatoire Perkins (Delaware, Ohio, U. S. A.) (2). Les résultats de ces observations indiquent une augmentation très remarquable dans l'intensité des ondes en coïncidence avec la diminution du nombre des taches du dernier cycle (minimum 1933,8). La correspondance étroite entre la courbe de transmission des ondes et celle des taches dans la zone centrale du soleil entre 1930 et 1932 semble indiquer que, lorsque les taches

(1) « Terrestr. Magn. », *39*, 1934, p. 201.

(2) « Perkins Obs. Misc., Sc. Pap. », *13*, *14*, *17*; 1932. — « Proceed. Fifth Pacific Sc. Congress », Canada 1933, p. 1065. — STETSON, *Earth, radio and the stars*, New York, 1934.

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se trouvent près de la direction soleil-terre, elles ont une influence plus grande sur les transmissions radio.

Bien que les résultats de STETSON ne soient pas douteux, il serait nécessaire qu'ils fussent confirmés par l'autres observations effectuées sur un plus long intervalle de temps. Il faut faire une remarque analogue au sujet des observations qui permettraient d'établir que les régions *M* ont une influence perturbatrice sur la propagation des ondes analogue à celle qu'elles ont sur le magnétisme terrestre.

Comme le remarque STETSON 1): «If a sufficient number of co-operating observers could be obtained in the neighbourhood of established broadcasting stations occupying clear channels, it should become possible ultimately to construct daily maps with lines of equal radio intensity surrounding the several broadcasting stations selected, resembling the daily weather map in appearance. Studies of these areas of high and low intensity in radio reception, and their migrations, would probably do far more towards the solution of the riddle of solar and terrestrial relations than any number of isolated investigations could of themselves perform ».

Récemment J. H. DELLINGER (2) a observé que les perturbations sur la propagation des ondes radio se reproduisent parfois à des intervalles de temps égaux à la période de rotation du soleil. L'évidence radio du phénomène se traduit par une brusque disparition des signaux radio de haute fréquence à grande distance, la durée complète du *fading*, étant d'environ 15 minutes. Ce phénomène a été observé le 20 mars, 12 mai, 6 juillet et 30 août 1935, à des intervalles égaux à peu près à deux fois la période de rotation solaire.

R. S. RICHARDSON (3) essaie de mettre en relation les perturbations observées par Dellinger avec les perturbations solaires en prévoyant aussi, d'après celle du 31 août une nouvelle perturbation le 24 octobre suivant. Les observations solaires sont celles de Mont Wilson dont Richardson en déduit la conclusion suivante: « Eruptions of bright hydrogen, such as those of august 30 and october 24 are not common,

(1) « Proceed. Fifth Pacific Sc. Congress », Canada 1933, p. 1074.

(2) J. H. DELLINGER, *A new cosmic phenomenon*, «Science », vol. 82, 1935, pp. 351-548. Aussi: « Phys. Rev. », Oct. 15, 1935.

(3) « Publ. Astr. Soc. of the Pacific », vol. 47, San Francisco (1935), p. 324.

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but it must be emphasized that we have photographs of much larger and more brilliant outbursts with no apparent terrestrial effects. Any theory seeking to connect disturbances of the earth's magnetic field or radio reception with sun-spot activity must naturally explain such observations ».

A. M. SKELLETT (1) du *Bell Telephone Laboratories* à New York apporte aussi à ce sujet une importante contribution, en comparant les *radio character figures*, représentant les conditions plus ou moins perturbées de propagation des ondes courtes sur l'Océan Nord-Atlantique avec l'activité magnétique terrestre. D'après ces statistiques on déduit une tendence à une récurrence des phénomènes chaque 27 jours de telle façon qu'on peut faire des prévisions utiles aussi pour le commerce.

Par les observations de Skellett, il en résulte un retard d'un jour des perturbations sur la propagation des ondes en rapport des perturbations solaires, comme il se présente pour les perturbations dans le magnétisme.

Absorption dans la haute atmosphère terrestre.

G. LOVERA (2) donne un résumé très complet des différentes méthodes de mesure de l'ozone atmosphérique, des recherches sur sa répartition au voisinage du sol et des hypothèses sur sa formation et sa dissociation.

Des mesures sur l'ozone atmosphérique ont été faites entre 1929 et 1932 à l'Observatoire solaire de Mont Stromlo, Canberra (Australie), par A. J. HIGGS (3), par la méthode de DOBSON. Il constate une forte variation annuelle, avec un maximum au printemps et un minimum à l'automne. Les époques de maximum et de minimum et leurs valeurs absolues sont d'accord avec les mesures faites dans les autres parties du monde.

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(1) « Trans. Americ. Geophys. Union. Sixteenth Ann. Meet », Part I, Washington (1935), p. 26.

(2) « Bollett. del Comit. Geodesia e Geofisica, Cons. Naz. Ricerche », anno V, luglio 1935, p. 153.

(3) « Memoirs Commonwealth Sol. Observ. », nr. 3, march 1934.

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Pendant l'année polaire DAUVILLIER (1) a fait aussi par une méthode chimique, le dosage quotidien de l'ozone au Scoresby-Sund. Ces dosages ont été contrôlés par quelques mesures spectrographiques et photoélectriques. Le résultat essentiel de ces mesures a été de montrer une accumulation extraordinaire de l'ozone près du sol, au début de la nuit polaire. La teneur de l'air en ozone retombe à des valeurs normales dès que le soleil illumine la troposphère.

La mesure de l'ultra-violet solaire extrême, faite aussi par DAUVILLIER à Scoresby-Sund, montre une variation saisonnière de ce rayonnement avec une dissymétrie par rapport au solstice. L'intensité est notablement plus grande en mai qu'en juillet ; la variation de la hauteur du soleil étant symétrique par rapport au solstice, ce résultat montre une absorption plus grande en juillet qu'en mai et est à rapprocher de la variation correspondante de la teneur en ozone, trouvée pendant cette période.

A l'aide d'un dispositif nouveau I. RANZI (2) a fait des recherches sur la distribution de la densité ionique dans la photosphère et ses variations en fonction des conditions météorologiques et du rayonnement solaire, en 1931-32. Les recherches font, entre autres résultats, ressortir une corrélation entre la troposphère et la première couche ionisée (*E*) ; l'auteur constate qu'à des accroissements anormaux de la densité ionique correspondent, pour la région *E*, des situations isobariques particulières. D'après RANZI, on peut interpréter ces anomalies par la pénétration plus grande des radiations électroniques résultant de la diminution de densité des gaz de l'haute atmosphère. Ces régions de moindre densité seraient elles-mêmes liées à des conditions de pression déterminées dans la troposphère.

Les recherches de BERKNER et WELLS sur la ionosphère effectuées en 1933 à l'Observatoire magnétique de Huancayo (Pérou) du *Department of terrestrial magnetism of the Carnegie Institution* sont exposées par BERKNER dans un rapport reproduit plus loin (p. 101). D'autre part, KIRBY et JUD-

(1) « Journal de Physique » ser. VII, vol. V, sept. 1934, p. 455.

(2) « Rend. R. Accademia dei Lincei », vol. 16, Roma 1932, p. 40. — « Nuovo Cimento », vol. 10, Bologna 1933, p. 21.

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SON (1) du *Bureau of Standards* ont aussi poursuivi des études sur la ionosphère ; ils ont publié des diagrammes de la variation diurne de la fréquence critique de la couche *E* et ses relations avec la force ionisante du soleil, pour les trois saisons comprises entre juin 1933 et novembre 1934. Des diagrammes analogues ont été construits pour la couche *F*, la courbe saisonnière de fréquence critique à midi, et la courbe des plus hautes fréquences critiques.

Une connexion remarquable entre la teneur en ozone et les différentes caractéristiques des hauts niveaux de l'atmosphère à été mise en évidence spécialement par DOBSON (2). Celui-ci a proposé récemment qu'une coopération internationale soit organisée pour créer en Europe un réseau de stations où serait mesurée la quantité d'ozone contenue dans l'atmosphère. Les corrélations qu'il a calculées semblent plus étroites pour certaines caractéristiques de la stratosphère que pour la troposphère. Les corrélations avec la densité et la température potentielle sont celles qui apparaissent les plus élevées et il semble qu'elles augmentent avec l'altitude jusqu'à 18 km., au-delà, les données météorologiques sont insuffisantes pour permettre de conclure. Il est évident que des recherches systématiques de ce genre peuvent avoir beaucoup d'importance pour préciser les relations entre les phénomènes solaires et terrestres.

De nouvelles mesures sur l'ozone en relation au cycle de l'activité solaire ont été exécutées récemment par J. E. FOWLE (3) de l'Observatoire astrophysique de la *Smithsonian Institution*. La quantité d'ozone observée à Harqua-Hala, Table Mountain et Montezuma, dans les années passées semble être en étroite corrélation avec les nombres des taches solaires, dans le sens que, autant plus grand le nombre des taches, autant plus grande était la quantité d'ozone. D'après les mesures plus récentes on doit en conclure que une telle relation, si elle existe, n'est pas encore bien établie.

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(1) « Journ. of Research Nat. Bureau of Standards », vol. 14, april 1935, p. 469.

(2) Voir : « Troisième Rapport », p. 42.

(3) « Trans. Americ. Geophys. Union. Sixteenth Meeting », P. I, Washington (1935), p. 164.

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Rayonnement cosmique.

L' influence que peut avoir le rayonnement solaire ou les variations de l'activité solaire sur le rayonnement cosmique a fait sujet de divers travaux.

Des mesures systématiques de l'intensité du rayonnement cosmique ont été exécutées par V. F. HESS, H. GRAZIADEI et R. STEINMAUER (1) entre 1931 et 1934, sur le Mont Hafelekar (2300 m.) près d'Innsbruck. Ils trouvent une variation diurne dépendant du temps solaire, le maximum d'intensité ayant lieu à midi et le minimum entre 21^h et 3^h. L'amplitude de cette variation diurne n'étant pas de plus de 3 ou 4 pour mille de l'intensité totale. On peut attribuer cette variation, soit à une action directe du soleil aux rayons cosmiques, soit à une différence dans le rôle d'écran joué par la haute atmosphère, à cause de la différence d'intensité des champs électriques verticaux qui se trouvent là pendant le jour et pendant la nuit. On a aussi observées des variations irrégulières du rayonnement cosmique, dont la cause doit probablement être recherchée dans les variations d'intensité du champ magnétique terrestre. A l'Observatoire Hafelekar les observations continues des rayons cosmiques ont été effectuées avec deux appareils Steinke Standard et un troisième à Innsbruck (580 m.) avec aussi des tubes Geiger-Müller.

Des recherches sur les rayons cosmiques ont été effectuées également par DAUVILLIER (2) au Scoresby-Sund, pendant l'année polaire, à l'aide d'un appareil absolu de Wulf-Kolhörster et deux variomètres ; les mesures ont porté sur l'effet de latitude, sur l'effet barométrique et sur les variations de l'intensité ou « activité » comparativement aux activités aurorale ou magnétique et à l'activité solaire. Ces dernières mesures ont été effectuées d'une manière permanente et sans interruption avec une chambre à haute pression, blindée ou non, soit dans le laboratoire, soit dans la grotte de neige.

(1) « Sitzungber. Akad. der Wissen. Wien. Math-Nat. », Kl. Abt II a, 143 Band, 5 und 6 Heft, Wien 1934, p. 313.

(2) « Journ. de Physique », ser. VII, vol. V, décembre 1934, p. 640.

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En première approximation (à 1 pour 100 près), le résultat est qu'il n'existe aucune relation entre l'intensité moyenne des rayons cosmiques et les activités solaire ou aurorale.

Voici, du reste, ce qui dit DAUVILLIER (1) sur cette question si importante et si discutée :

« Cette question a été l'objet d'observations récentes de HESS au Hafelekar et de CORLIN (2) à Abisko, utilisant tous deux l'enregistreur sensible et précis de Steinke. Des influences très faibles, mais contradictoires, ont été observées : ainsi CORLIN avait trouvé en 1929-30, avec un appareil de Kolhörster, une intensité plus forte pendant les aurores, tandis qu'en 1932-1933 avec l'appareil plus précis de Steinke, cette corrélation disparût. Par contre, l'intensité variait pendant cette dernière période avec l'activité solaire, ce qui indiquerait l'emission d'un faible rayonnement cosmique (quelques millièmes) par le soleil sous forme de photons. Ce résultat est en accord avec la variation diurne (maximum) de 2/1000 à 12^h de temps local, au niveau de la mer, trouvée par HESS et ses collaborateurs. D'autre part, HESS et STEINMAURER (3), ne trouvent aucune relation avec l'activité solaire et observent contrairement au résultat de CORLIN, une très faible diminution de l'intensité au début des orages magnétiques. Il faut attendre de nouvelles recherches avant de pouvoir conclure. Il en est de même pour d'autres sujets controversés tels que l'effet barométrique de second ordre, l'influence de la température extérieure, de l'humidité, de la nébulosité, etc.

Les faibles variations observées au Scoresby-Sund se retrouvent-elles sous d'autres latitudes? CORLIN a publié une courbe analogue pour l'année polaire à Abisko. Quelques détails semblent se retrouver mais la ressemblance demeure incertaine.

Les meilleures mesures seraient évidemment effectuées dans une grotte de neige d'épaisseur constante. Pour nous rapprocher de ces conditions idéales, nous avons fait édifier sur la terrasse supérieure de l'Observatoire de Meudon, une chambre d'observation métallique complètement entourée par

(1) l. c., pag. 646.
(2) « Annals of the Observatory of Lund », 1934, nr. 4.
(3) « Nature », octobre 1933, t. *132*, p. 601.

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une épaisseur d' un mètre d'eau distillée. Ce réservoir, calorifugé et de grande inertie calorifique, sera maintenu, en outre, à une température constante au moyen d'un thermostat électrique ». Cette chambre est destinée à recevoir l'enregistreur employé par DAUVILLIER à Scoresby-Sund.

Lumière du ciel nocturne.

LORD RAYLEIGH et H. SPENCER JONES (1) viennent de publier un mémoire important sur la luminosité du ciel nocturne et ses variations, où ils discutent les observations systématiques qui ont été faites aux stations de Terling, Canberra et Le Cap entre 1933 et 1934. Ces observations concernent trois régions du spectre autour de raie verte de l'aurore, dans le bleu et dans le rouge. Les auteurs ont reconnu une variation annuelle dépendant soit de la latitude magnétique, soit de celle géographique et qui doit probablement devenir insignifiante à l'équateur. L'amplitude de la variation annuelle dans les régions spectrales de l'aurore et dans le rouge est à peu près la même, tandis que l'amplitude dans la région bleue est beaucoup plus faible. On constate aussi une variation lente de l'intensité de la région aurorale dont les valeurs annuelles moyennes sont en corrélation très étroites avec les aires moyennes de taches solaires ; cependant, la relation entre la luminosité du ciel nocturne et l'activité magnétique terrestre n'apparaît pas aussi clairement.

Nous ne faisons que mentionner ici les très rémarquables recherches de J. DUFAY et J. CABANNES (2) sur la variation annuelle de l'intensité des raies brillantes du ciel nocturne car elles sont exposées par eux-mêmes dans une note de ce Rapport (p. 135).

Une importante contribution à la photométrie du ciel nocturne avec des considérations relatives à la lumière zodiacale et aux phénomènes crépusculaires a été exécutée par W. BRUNNER (3). Pour ce qui concerne la corrélation entre

(1) « Proceed. R. Soc. of London », Ser. A, nr. 872, vol. 151, august 1935, pp. 22-55.
(2) « Comptes Rendus Ac. Sc. », *200*, 1934, pp. 878-1504.
(3) « Publik. Eidgenöss Sternwarte », vol. VI, Zürich, 1935.

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intensité du ciel nocturne et activité solaire l'auteur constate que les données de différents observateurs permettent, dès à présent, d'établir une corrélation certaine entre les deux phénomènes, à condition toutefois de prendre comme caractéristique de l'activité solaire pour un lieu et une période déterminés la fréquence des aurores polaires. Des longues séries de mesures faites en coopération, à différentes longitudes et latitudes, sont encore nécessaires pour préciser les rapports existants entre les deux phénomènes.

Variations météorologiques et climatologiques sur la terre.

Les mesures si nombreuses de la constante solaire, faites par la *Smithsonian Institution*, sous la direction de ABBOT (1), on conduit celui-ci aux conclusions suivantes, en ce qui concerne l'action possible des phénomènes solaires sur les variations météorologiques terrestres :

« The periodicities in solar variation and other periodicities which are all integral submultiples of 23 years occur in departures from normal temperatures and precipitations at numerous terrestrial localities. The inference is that solar changes influence weather. Changes of phases and amplitudes occur in these terrestrial periodicities. On account of the integral relationship of the terrestrial periodicities to 23-years, the weather at all stations contains features which tend to repeat themselves at intervals of 23 years. Various phenomena depending on weather show the influence of the 23-year cycle. Among those examined are the level of the Nile River, the levels of the Great Lakes, the rainfall of Southern New England, the widths of tree rings, the abundance of cod and mackerel, the thickness of varves of Pleistocene and Eocene ages ».

Une contribution nouvelle sur la relation des périodes météorologiques avec les périodes solaires à été récemment publiée par H. HELM CLAYTON (2) où on démontre qu'une

(1) « Smith Miscell. Coll., » vol. 94, nr. 19, Washington 1935, pag. 88.

(2) « Trans. Americ. Geophys. Union. Sixteenth Meet », Part I, Washington (1935), p. 158.

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augmentation des « centres d'action » dans l'atmosphère terrestre à l'augmentation de l'intensité solaire est caractéristique de toutes les périodes météorologiques, ce qui appuie les résultats de C. J. KULLMER sur la marche des pressions barométriques.

Une relation entre les variations de témperature dans une certaine localité et la période de rotation solaire, semble avoir été mise en evidence par K. F. WASSERFALL (1). Il considère la témperature de Oslo (Norvège) et il fait noter en celle-ci une période de 27 jours, non seulement, mais en plusieurs années il remarque des oscillations, en cette période, comprise entre 30 et 26 jours. Ces observations semblent en accord avec les périodes des rotations des zones solaires de latitude successivement occupées par les taches pendant le cycle undécennal.

Sur les variations des anneaux annuels des arbres qui révèlent, à travers les variations de climat, une relation avec le cycle undécennal de l'activité solaire, A. E. DOUGLAS nous a déjà reinsegné en 1931 (2), ensuite en 1933 il a resumé l'ensemble de ses recherches (3) au cours desquelles environ un demi-million d'anneaux ont été examinés sur près de 5000 variétés différentes d'arbres. 250.000 anneaux, après qu'ont en eut déterminée l'époque ont été mesurés avec beaucoup d'attention excéptés naturellement les anneaux des arbres géologiques. Douglas confirme les resultats déjà obtenus sur la correspondance des cycles terrestres et les solaires et même si les premiers sont parfois complexes, la stabilité en apparaît comme la caractéristique principale. On y peut noter, d'autre part, des changements analogues à ceux qu'on rencontre dans des cycles solaires successifs, mais ils présentent en outre plusieurs périodes superposées, ce qui prête à confusion. On peut expliquer ce fait par la persistance des cycles après que la cause qui les produisait — peut être un caractère biologique — a disparu.

DOUGLAS observe enfin que les arbres étudiés jusqu'ici appartiennent à des régions étroitement limitées sur le globe;

(1) « Trans. Americ. Geophys. Union. Sixteenth Meet », Part I, Washington (1935), p. 161.

(2) « Troisième Rapport », p. 45.

(3) « The Scientific Monthly », dec. 1933, p. 481.

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il serait intéressant d'étendre le travail particulièrement, près du cercle polaire arctique, où un bon materiel a été recueilli et non encore utilisé à fond. Il est évident que la répartition sur la terre des effets du rayonnement solaire est très complexe et certaines régions seront plus difficiles à étudier que des autres. Les réactions biologiques sur la croissance des arbres probablement, pour les différents lieux, n'a pas seulement la raison d'être dans la pluie ou l'humidité atmosphérique, mais sont soumises à d'autres facteurs dont le rôle doit être très complexe.

Les notes qui suivent ont été communiquées par les auteurs eux-mêmes et rendent compte des progrès effectués au cours des trois dernières années dans les diverses questions qui intéressent notre Commission.

GIORGIO ABETTI.

Je tiens à exprimer à Monsieur et à Madame L. D'AZAMBUJA toute ma reconnaissance pour l'aide très précieuse qu'ils ont bien voulu me donner pour la compilation du présent Rapport.

G. A.

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NOTE SUR LES PROGRÈS RÉCENTS DANS L'ÉTUDE DES RELATIONS ENTRE LES PHÉNOMÈNES SOLAIRES ET TERRESTRES

par

CH. FABRY.

L'étude de ce problème s'est développée dans deux directions :

I. — Continuation de l'étude des phénomènes où l'influence solaire est certaine.

II. — Etude de nouveaux phénomènes terrestres dans lesquels une influence solaire est possible ou soupçonnée, mais non encore certaine.

I. — Dans la première catégorie rentrent les phénomènes suivants :

1) *Magnétisme terrestre.* — Dans cette question, où l'influence solaire est certaine, un point très important est de savoir s'il existe un intervalle de temps entre l'apparition d'une perturbation solaire et l'action constatée sur le magnétisme terrestre. Une étude critique des faits déjà publiés a été faite par M. MAURAIN (p. 73).

2) *Aurore polaire.* — L'étude de ce phénomène est continuée par les physiciens norvégiens. On peut espérer que les observations (non encore publiées) faites pendant « l'année polaire » apporteront des résultats nouveaux.

Il faut citer, à propos de l'aurore polaire, la nouvelle théorie de M. DAUVILLIER, d'après laquelle les rayons cathodiques producteurs de ce phénomène seraient des « rayons

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secondaires » engendrés dans un gaz ultrarareﬁé qui existerait autour de la terre jusqu'à des distances de quelques milliers de kilomètres. Les « rayons primaires » venant du soleil auraient des vitesses presque égales à celle de la lumière, avec une énergie de l'ordre de 10^{10} électrons-volts. Cette théorie mérite d'être prise en considération, bien qu'on ne puisse dire encore si elle représente vraiment la réalité.

3) *Etude de l'ionosphère.*

4) *Phénomènes proprement météorologiques.*

Je n'ai rien de particulier à dire sur ces deux catégories, qui sortent du cadre de mes études.

II. — Dans un certain nombre de phénomènes terrestres on peut supposer une influence solaire, sans que cette influence soit certaine.

1) *Ozone atmosphérique.* — Les variations de l'ozone atmosphérique sont déjà bien étudiées d'une manière empirique; mais la théorie de la formation de l'ozone est encore incertaine. DAUVILLIER a publié une théorie d'après laquelle la formation de l'ozone aurait la même cause que l'aurore polaire, et serait par suite liée à l'activité solaire. De ses observations faites au Groenland pendant l'année polaire, Dauvillier croit pouvoir conclure que les fortes teneurs en ozone dans les régions boréales sont effectivement liées aux fortes activités solaires. Le nombre des observations est encore trop faible pour entraîner une certitude; de nouvelles observations sont nécessaires. M. Dauvillier espère les faire, avec MM. CHALONGE et VASSY, dans une station au Nord de la Russie pendant l'hiver 1934-35.

2) *Lumière du ciel nocturne.* — Les progrès des appareils spectrographiques ont permis une analyse assez détaillée du spectre de cette lumière. Une étude très complète (non achevée, en partie publiée) a été faite par MM. CABANNES, DUFAY, GAUZIT, GARRIGUE, au moyen de spectrogrammes pris en partie au Pic-du-Midi et en partie à Montpellier. On trouve un spectre d'émission très complexe, provenant probablement de la haute atmosphère sous une excitation provenant du Soleil. Ce spectre est, en partie, identique à celui de l'aurore polaire, et en partie différent. Il semble y avoir des modifications d'une époque à une autre, comme l'avait indiqué Lord RAYLEIGH. Une influence solaire est possible, mais non encore démontrée. Une coopé-

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ration pour cette étude serait très désirable ; malheureusement peu d'observatoires astronomiques sont placés de telle manière que cette étude soit possible.

3) *Rayons cosmiques.* — Les théories admises jusqu'en 1933 attribuaient aux rayons cosmiques une origine extérieure au système solaire. Récemment, M. DAUVILLIER a publié une théorie où l'origine est purement solaire. Si cette théorie était exacte, on devrait constater une influence des phénomènes solaires sur les rayons cosmiques. Si une telle influence existe, elle est certainement très faible ; il est impossible d'affirmer qu'elle est réellement nulle.

4) *Rayonnement ultra-violet reçu du Soleil à la surface de la terre.* — De nombreuses mesures ont été faites par PETTIT au Mont Wilson sur le rapport entre le rayonnement ultra-violet et le rayonnement visible venant du soleil à travers l'atmosphère terrestre. Ce rapport montre d'importantes variations. Il reste à savoir si elles sont d'origine purement solaire ou si elles sont produites par des variations dans l'absorption atmosphérique. Dans les deux cas, ces variations sont intéressantes pour les relations entre la terre et le soleil. Si ces variations sont réellement solaires, elles doivent avoir une répercussion importante sur les phénomènes terrestres. Si elles sont d'origine atmosphérique, on est en présence d'une variation terrestre qui a probablement une cause solaire. La question reste ouverte.

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RADIATION SOLAIRE
PHÉNOMÈNES SOLAIRES.

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ON THE SOLAR RADIATION IN THE ULTRA-VIOLET REGION OF THE SPECTRUM

by

W. E. BERNHEIMER.

The study of the intensity of the ultra-violet solar radiation is of very great value in various solar problems and also in the investigation of possible relationships with terrestrial phenomena. All interested in these problems are greatly indebted to E. PETTIT not only for having devised a new method (1) for observing the ultra-violet radiation in the region 3200A but also because he has undertaken observations on every favourable day during the past 10 years as part of the routine work of the Mount Wilson Observatory.

The method employed, with some considerations on the results obtained, have been given in the three preceding Reports (2). In 1932 Pettit published an exhaustive paper (3) on the instruments and methods used with a discussion on the errors of observation.

The material now available is considerable and is most useful for various investigations. Taking April 1925 as the beginning of the regular series we have, to March 1935 incl., data for 10 complete years covering 2333 days of observations.

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(1) PETTIT E., « Publ. A. S. Pac. », 38 p. 21 (1926), « Pop. Astr. », 34, p. 631 (1926), « Wash. Nat. Ac. Proc. », p. 380 (1927).

(2) PETTIT E., « Comm. Solar and Terr. Rel. », I Rep. p. 54 (1926), II Rep. p. 91, III Rep. p. 105 (1931).

(3) PETTIT E., « Ap. J. », 75, p. 185 (1932).

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The distribution of the material is shown in Table I. It will be noted that there are on the average 230 days of observation in each year.

TABLE I.

Observations of ultra-violet solar radiation now available.

Period				Days of Observation
April	1925	to March	1927	380
»	1927	»	1929	459
»	1929	»	1931	508
»	1931	»	1933	490
»	1933	»	1935	496
April	1925	to March	1935	2333

Excluding the first period the yearly average amounts to about 250 days, a very high figure. In the Bulletins of the I. A. U. published quarterly in Zürich the daily values of the ratio ultra-violet/green are given, all the values are extrapolated to air-mass, m = 0. As the Mount Wilson observations show practically no variations in the green region, Pettit considers that the somewhat large variations of the ratio UV/ green amounting to more than 40 % may be regarded as variations of the extra-terrestrial ultra-violet solar radiation. The writer in several papers has raised some objections to the assumption of real extra-terrestrial variations of solar intensity. The main arguments may be seen from the following :

1) The reflected solar light in or near the spectral region concerned, as observed on planets and satellites by photoelectric methods never shows variations greater than 1 per cent.

2) The invariability of the ratio « zenith to space »

$$\frac{\text{UV/green } (m = 1)}{\text{UV/green } (m = 0)}$$

pointed out by Pettit, seems to be difficult to reconcile with the assumption that the ratio UV/green determined for

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m = 0 is really that for a solar radiation free from terrestrial influence.

3) A search for terrestrial effects in the definitive values has been successful. In 1928 it was first shown (1) that the monthly means of the ultra-violet radiation, assumed to be extra-terrestrial, indicate the occurrence of an annual varia-

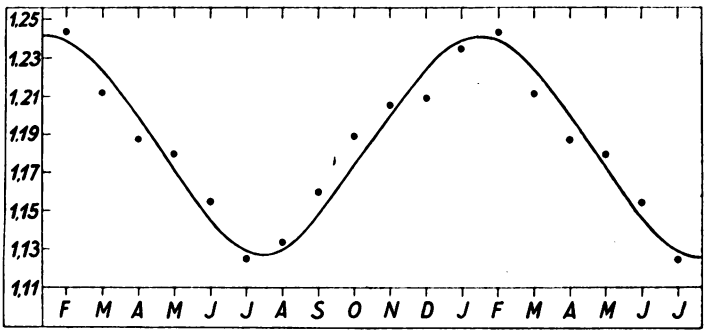

Fig. 1. — The annual period of ultra-violet solar radiation attributed to terrestrial influence. The curve is based upon 2333 days of observations covering 10 years from April 1925 to March 1935.

tion. The annual period was established later with the aid of additional material. The data obtained from 1312 days between April 1925 and December 1930 have been investigated in the III Report and a curve representing the annual period is reproduced therein, p. 17, fig. 1E. The material given by the first eight complete years has been investigated by the writer in 1933 (2), the annual period appears very distinct in the whole period, as well as in every sub-group of 2 or 4 years.

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(1) BERNHEIMER W. E., « Die Naturw. », 16, p. 26 (1928), « Handb. d. Astroph. », IV, p. 1 (1929) and « Monthly Weather Rev. », 57, p. 412 (1929), « Meteor. Z. », 47, p. 190 (1930), « Lund Obs. Circ. », N. 2, p. 17 (1931), « Comm. Solar and Ter. Rel. » III Rep. p. 16 (1931), « Handb. d. Astroph. », I, p. 407 (1933), « Handb. d. Astroph. », VII (1935).

(2) BERNHEIMER W. E., « Sitz. Ber. d. Akad. d. Wiss. », Wien, 142, p. 449 (1933).

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As a final test if we take all the observations between April 1925 and March 1935, covering 120 months and 2333 days of observations, the very extensive material definitely confirms the annual period first suggested in 1928. A curve

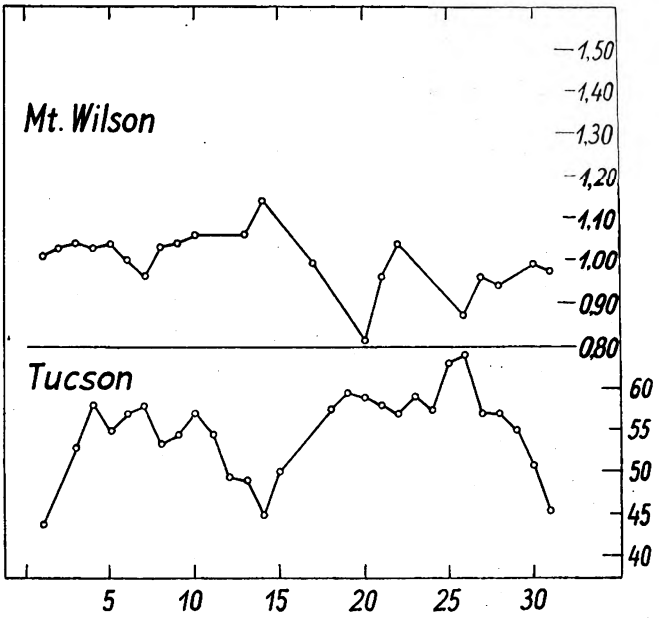

Fig. 2. — The anomalous run of ultra-violet solar radiation as observed in May 1931 at Tucson compared with simultaneous observations at Mount Wilson.

showing the terrestrial effect in the measurements of the ultra-violet solar radiation according to the last calculations is given in figure 1.

It would be of the greatest use, as suggested by the writer in 1929 and in 1931, to begin simultaneous observations in the southern hemisphere in order to obtain an independant confirmation of the terrestrial effect. Hitherto only simultaneous measurements in the northern hemisphere

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(Tucson) (1) have been published in 1933 for the period February 1930 to June 1932, the observations with identical instrumental means are published without reduction to air-mass m = 0. Two points may be mentioned concerning this material.

1) It will be seen that anomalous variations occur in the Tucson observation not only in the ultra-violet but also in the green radiation. It is interesting to note that the variations in the green region are sometimes greater than in the ultra-violet.

2) DAVIS and MCCARTHY suppose that the variations observed by them are mainly due to different terrestrial influences. In some cases, especially mentioned, a real variation of the ultra-violet solar radiation is assumed, these significant values are published in detail. It would be a conclusive test of the reality of extra-terrestrial variations if the anomalous behaviour observed at Tucson appeared also in the simultaneous Mount Wilson observations, but this is not the case. The values for May 1931 held to be anomalous by the Tucson observers are plotted together with the Mount Wilson simultaneous values in fig. 2. It is evident that the run of the two curves show no correlation. A series of simultaneous measurements at different places is most desirable as being the best way in the future to prove the theory of the reality of short period extra-terrestrial variations.

A very interesting problem, first pointed out by Pettit (2), is the behaviour of the ultra-violet radiation in and near maximum and minimum of solar activity. It was at one time supposed that the ultra-violet radiation is closely correlated with sunspot frequency (see III Report, p. 105); the writer held a different opinion, expressed in Report III and elsewhere. The data now at hand admit the study of the last minimum of solar activity. In fig. 3, on the left, the original values of the monthly means from 1931 to 1933 of the sunspot relative numbers and ultra-violet solar radiation, as given in the Bulletin of the I. A. U., are plotted. It will be noted that there is a correlation in the run of the two quantities but it is not

(1) DAVIS C. E. and MCCARTHY I. L., « Monthly Weather Rev. », 60, p. 237 (1933).

(2) « Mt. Wilson Report », 1933-34, p. 125 (1934).

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well pronounced, the unexpected fact of a considerable difference in the times of the minimum values is conspicuous.

The behaviour of the sunspot numbers and the ultra-violet radiation in and near minimum of solar activity can be studied

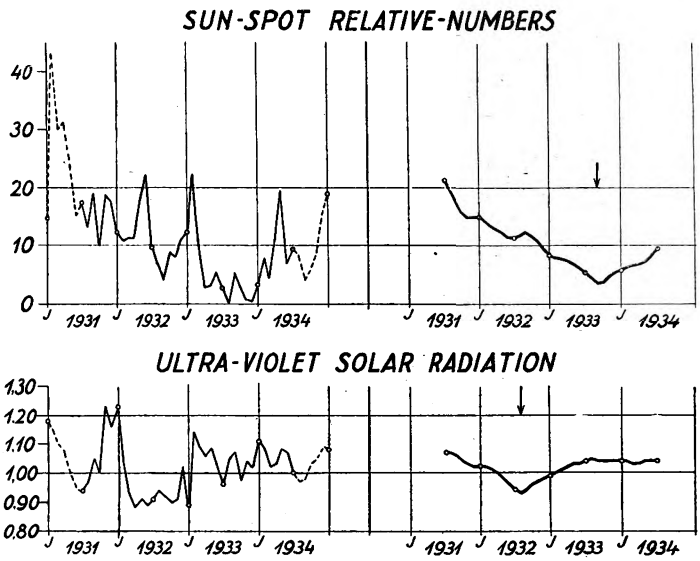

Fig. 3. – The sunspot relative numbers and ultra-violet solar radiation near the last minimum of solar activity. Left, uncorrected monthly means ; right, smoothed monthly means. The diagram shows a marked phase-shift for the two solar phenomena concerned.

better if smoothed monthly means are adopted, the formula used is given in a note published by the writer in Lund Circ. N. 2, 1931. Using this method, which has also been used for the treatment of other solar phenomena (1), secondary variations are eliminated, as well as the annual period mentioned above in the case of the ultra-violet radiation. The curves reproduced on the right hand side of fig. 3 are thus obtained;

(1) BERNHEIMER W. E., « Vierteljahrschrift d. Astron. Ges. », 70, N. 4 (1935) Prelim. note.

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the minimum for both quantities is well marked and the displacement in phase is clearly shown. The minimum ultra-violet radiation occurred not less than 13 months before. Using the method described above this remarkable phase-shift has also been found in the last maximum period, and it

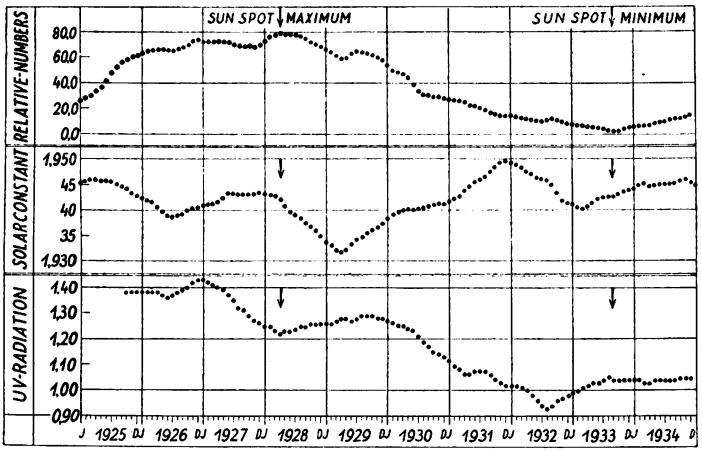

Fig. 4. — The general run of the sunspot relative numbers, the solar constant and the ultra-violet radiation according to the smoothed monthly means of all observations available since 1924.

may be mentioned that the displacement not only has the same sign (fig. 4) but is also of the same order of magnitude, namely 15 months. The occurrence of analogous phase-shifts of other solar phenomena has been investigated by the writer (1) and it is found that a displacement in the same direction, as observed for the ultra-violet radiation occurs only with extreme values of the ellipticity of the solar corona. In all other solar phenomena the displacement is in the opposite direction, namely the minimum and maximum occur later than the minimum and maximum of sunspot relative numbers.

(1) BERNHEIMER W. E. «Vierteljahrschrift d. Astron. Ges.», 70, N. 4 (1935), Prelim. note.

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It would be interesting in the future to investigate more thoroughly a suspected connection between ultra-violet radiation and the form of the solar corona.

The phase-shift of more than one year found above does not warrant the statement that ultra-violet radiation and solar activity are intimately connected. The run of the two quantities has only a general similarity (compare the first and third curve of fig. 4), it is less for uncorrected monthly means, more for smoothed means. For shorter periods no correlation exists, or if it does it tends towards the negative or the positive as may be seen from Table II giving the respective coefficients of correlation. The different character of different periods is very remarkable.

TABLE II.

The correlation between ultra-violet radiation and sunspot numbers.

N°	36	35	34
Period	Oct. 1925 to Sept. 1928	Oct. 1928 to Aug. 1931	Sept. 1931 to June 1934
Monthly means (uncorrected)	$+0.173 \pm 0.162$	$+0.602 \pm 0.108$	$+0.124 \pm 0.169$
Monthly means (smoothed)	-0.559 ± 0.115	$+0.981 \pm 0.006$	-0.434 ± 0.139

The difference in the run of sunspot numbers and ultra-violet radiation may finally be illustrated as in Table III by the last published uncorrected data from 1935.

TABLE III.

Sunspot numbers and ultra-violet radiation, January to June 1935.

MONTHS	January	February	March	April	May	June
Sunspot numbers (uncorrected)	18.9	20.5	23.1	12.2	27.3	45.7
Ultra-violet radiation (uncorrected)	1.01	1.07	1.15	1.11	1.02	0.94

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It will be seen that the sunspot numbers already are relatively high in January and increase further to 45.7 in June, quite a normal value in the cycle for the phase concerned. The values for the ultra-violet radiation are low in general and decrease further to 0.94 in June, an unexpected value of minimum radiation for the phase under consideration. The discrepancy is all the more marked if the data for the same phase in the former cycle are compared. Thus, for example, in May 1925 with a sunspot number of the same order of magnitude, namely 42.8, the value of the ultra-violet radiation is 1.37, more than 40 % higher than in the present cycle.

In fig. 4, which is an extension with new material of fig. 2 p. 20 in the III Report the run of the smoothed monthly means of the solar constant observed in the same period may be noted. An inspection of the curve shows at once that the solar constant runs very differently as compared with the ultra-violet radiation and the sunspot relative numbers. Indeed calculations show that there is no or negative correlation between the solar constant and the ultraviolet radiation ($r = -0.265 \pm 0.091$ taking 105 uncorrected monthly means) and between the solar constant and the sunspot relative numbers ($r = -0.404 \pm 0.082$ for 105 uncorrected monthly means), confirming the writer's earlier statements based upon less extensive material. The tendency of a negative correlation between the total radiation (solar constant) and the ultra-violet solar radiation may become of special interest, and because of theoretical considerations is quite an unexpected fact.

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COOPÉRATION INTERNATIONALE POUR LA SURVEILLANCE CONTINUE DE LA CHROMOSPHÈRE SOLAIRE AVEC LE SPECTROHÉLIOSCOPE

par

L. D'AZAMBUJA.

Parmi les phénomènes solaires auxquels on a cru pouvoir attribuer jusqu'ici les orages magnétiques terrestres et les perturbations connexes, les éruptions chromosphériques brillantes, localisées au voisinage des groupes de taches actifs, doivent retenir tout spécialement l'attention.

On sait que ces éruptions se manifestent par l'apparition presque soudaine, dans la plage faculaire entourant le groupe de taches, d'une masse aux contours changeants, plus ou moins étendue et qui, après avoir atteint un éclat parfois tout à fait exceptionnel, reprend en quelques heures, ou même en un temps plus court, l'intensité des régions voisines. L'éruption, comme on peut le voir quand elle se produit près du bord solaire, est presque toujours accompagnée de jets protubérantiels intenses, la masse principale restant localisée au niveau de la chromosphère. L'étude de l'effet Doppler-Fizeau révèle souvent dans les jets des vitesses radiales considérables (1).

Jusqu'à ces dernières années, ces phénomènes ne pouvaient guère (2) être reconnus et suivis qu'avec le spectrohéliographe,

(1) Les cas les plus typiques de ces éruptions ont été réunis récemment par G. E. HALE dans *The spectrohelioscope and its work*, III, Astrophysical Journal, vol. 73, p. 379 et Contributions from the Mount Wilson Observatory, nr. 425.

(2) Des éruptions intenses ont été observées parfois avec un simple téléspectroscope.

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complété par le spectro-enregistreur des vitesses de H. DESLANDRES. Mais, à cause de leur brièveté, du nombre relativement petit des appareils en service et du peu de temps consacré chaque jour dans les observatoires à l'obtention des spectrohéliogrammes, l'enregistrement d'une éruption était presque toujours le résultat d'un hasard favorable.

On les décèle plus aisément aujourd'hui avec le spectrohélioscope de G. E. HALE qui, d'un réglage facile et n'utilisant pas la plaque photographique, permet de répéter les observations quotidiennes avec une perte de temps minima et sans dépense supplémentaire. L'instrument renseigne d'ailleurs à la fois sur les formes et sur les mouvements des vapeurs étudiées. Il est clair cependant que le progrès ainsi réalisé est encore bien insuffisant si les observations ne sont pas en même temps coordonnées et effectuées en de nombreux points du globe convenablement répartis.

L'idée d'une coopération internationale pour assurer une surveillance plus efficace de la chromosphère solaire avec le spectrohélioscope, a été suggérée en 1931 par G. E. Hale (1) qui achevait alors la mise au point d'un modèle simple et relativement peu coûteux de l'instrument. Au Congrès de l'Union astronomique internationale, réuni à Cambridge (Mass.) en 1932, l'organisation de la coopération, qui avait été déjà préparée par C. E. ST. JOHN, président de la Commission de Physique solaire, a été, par suite de la subdivision de celle-ci en quatre commissions nouvelles, confiée à la Commission des phénomènes chromosphériques (Président, L. D'AZAMBUJA). Un centre a été créé à Meudon pour répartir les heures d'observation et grouper les résultats en vue de leur publication trimestrielle dans le *Bulletin for character figures of solar phenomena* (2).

A l'heure actuelle, seize observatoires munis, pour la plupart, de spectrohélioscopes du type « standard » de Hale, se sont déclarés en mesure de participer à la surveillance quotidienne de la chromosphère solaire. Un horaire général

(1) G. E. HALE, *Cooperative research with the spectrohelioscope*, Troisième Rapport de la Commission pour l'étude des phénomènes solaires et terrestres, p. 78.

(2) La première liste d'éruptions brillantes, observées pendant le deuxième trimestre 1934, a été publiée dans le Bulletin nr. 26.

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des heures d'observation conciliant, dans la mesure du possible, la commodité de chacun avec la nécessité d'éviter les lacunes, a été établi. Il est résumé graphiquement dans la

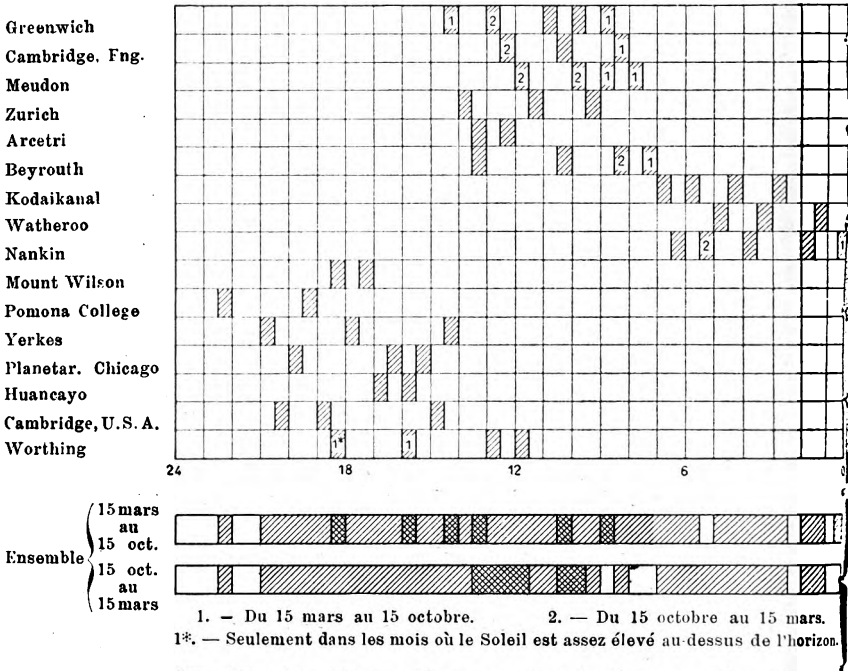

Fig. 1. — Horaire des observations en coopération avec le spectrohélioscope.

fig. 5 qui donne en même temps la liste des observatoires participants.

Dans les circonstances atmosphériques favorables, en été, la surveillance est dès maintenant assurée de 0 heure à 21 heures de Greenwich, avec seulement trois interruptions d'une demi-heure. Une lacune un peu plus importante subsiste entre 21 heures et 24 heures, le montage ou la mise au point des instruments, dans les observatoires qui devaient la combler, n'étant pas encore complètement achevés.

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CONDITIONS MAGNÉTIQUES DE LA TERRE ET COURANTS TERRESTRES.

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SOLAR INFLUENCES ON THE EARTH'S MAGNETISM AND ON THE UPPER ATMOSPHERE

by

S. CHAPMAN.

The following is a brief account of some of the work done by the writer and his collaborators since the last report of the Committee.

a) Magnetic Storms.

The following papers have been published on the new theory of magnetic storms, by the writer and V. C. A. FERRARO, mentioned in the last report:

Part I: *The initial phase*, « Terrestrial Magnetism », Vol. 36, pp. 77-97, 171-186 (1931), Vol. 37, pp. 147-156, and pp. 421-429 (1932).

Part II: *The main phase*, « Terrestrial Magnetism », Vol. 38, pp. 79-96 (1933).

A brief general account of this theory has been given by V. C. A. FERRARO in « The Observatory », Vol. 56, pp. 253-259, 1933.

The theory attributes magnetic storms to the action of a neutral ionized stream of particles from the sun. As they near the earth, currents are induced in the front surface of the stream, which tend to shield the interior of the stream from the earth's field. The external magnetic field of these currents is roughly that of a magnetic doublet at the image, relative to the surface of the stream, of the earth's centre. This field increases the horizontal magnetic field in the middle

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belt of the earth, as actually observed during the initial phase of the storm.

The front layer of the stream is retarded by the action of the magnetic field on the induced currents flowing in the layer. The side parts of the stream flow on relatively undisturbed, and thus the earth becomes enclosed in an open hollow space within the stream; the apex of the hollow is between the earth and the sun. The front layer of the stream is rapidly increased in density by the inflow of oncoming matter from behind, and the density and temperature there may be very greatly increased.

The second phase of the storm is supposed to arise by the formation of a ring current round the earth, by charged particles leaving the surface of the stream, on the side of the earth farthest from the sun, and bridging the hollow space. Surface charges from the stream may also be expected to flow, from the parts of the hollow surface near where it is cut by the earth's magnetic axis, towards the polar regions of the earth, there producing aurorae.

The magnetic effects are supposed to become appreciable when the apex of the hollow is at a few earth-radii from the centre of the earth. This distance is much less than the radius of the ring of electrons round the earth which occurs in STÖRMER's theory of aurorae, which he has also connected with magnetic storm phenomena and radio echoes of long delay. The difference implies a great discrepancy between the corresponding estimates of the field energy involved in a magnetic storm — a question discussed by the writer in *Terrestrial Magnetism*, Vol. 37, pp. 269-272, 1932.

The whole theory is necessarily both speculative and difficult; probably the most doubtful feature is that relating to the ring current, the existence and formation of which are still very uncertain.

b) Ionization of the Upper Atmosphere.

A second theoretical paper on the ionization of the upper atmosphere, calculated on simple physical assumptions, has been published (*Proc. Phys. Soc.*, Vol. 43, pp. 483-501, 1932), in which the curvature of the earth has been taken into ac-

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count. Thus the variations of ionization near sunrise and sunset are obtained more accurately.

On the basis of this paper, G. MILLINGTON (1) has prepared charts showing the geographical and time distribution of the maximum electron content (in any vertical column), at different seasons, and for different values of the physical magnitudes involved. Improved versions of these charts have recently been published (2); in particular they show the distribution and changes of (regular) ionization over the polar-regions.

c) *Solar eclipse effects on upper air ionization.*

Through discussions between Prof. E. V. APPLETON and the writer it became clear that a solar eclipse affords a very good means of determining whether the solar agent that ionizes the upper atmosphere is ultra-violet light (or some other agent travelling with similar speed) or neutral corpuscles (as suggested by the writer in his Bakerian Lecture [3]) travelling with a much lower speed. If this speed is 1,000 km. per sec., as suggested by E. A. MILNE'S work on emission of particles from the sun by radiation pressure, the eclipse of the corpuscular stream will affect a region far distant from that of optical eclipse, and at a time about two hours before the time of optical totality (4). Following upon a letter to *Nature* (1932, May 21) by Prof. Appleton and the writer, radio observations were made in many countries during two recent eclipses, to test whether the ionization suffered an optical or a 'corpuscular' eclipse, or both. In connection with the eclipses of August 31, 1932 and of August 21, 1933 maps of the corpuscular track were prepared by Dr. J. C. P. MILLER (5). References to the publications describing those observations are given in a report, by Appleton and the writer, to the 1934 London meeting of the International Union

(1) « Proc. Phys. Soc. », vol. 44 (1932), pp. 580-593.
(2) « Proc. Phys. Soc. », vol. 47 (1935), pp. 263-276.
(3) « Proc. Roy. Soc. », A, vol. 132 (1931), pp. 353-374.
(4) « Mon. Not. Roy. Ast. Soc. », vol. 92 (1932), pp. 413-420.
(5) « Nature », May 21 (1932), and July 1 (1933).

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for scientific radio telegraphy (U. R. S. I.) (1). Its general conclusion is that the main eclipse effects observed are in favour of ultra-violet light as the chief cause of the regular daily ionization in both the *E* and *F* layers, but that further examination of possible corpuscular eclipse effects is desirable. The writer has made, but not yet published, a theoretical investigation of the changes of ionization in the upper atmosphere during an eclipse, on the same physical assumptions as were used in his papers (see [*b*] above) in the *Proc. Phys. Soc.*

d) Solar eclipse effects on the daily magnetic variations.

A discussion of the effect which a solar eclipse would be expected to produce on the daily variation of the earth's magnetic field has been published by the writer (2). It is inferred that if the *E* layer be the seat of the electric currents which produce the daily magnetic variation, the magnetic effects of an eclipse should be measurable, and their nature is described. If however, the magnetic variation is produced in the *F* layer, the eclipse effects are likely to be too small for detection with certainty. The magnetic observations during past eclipses are discussed, and the opinion is expressed that they show no regular magnetic effect of the type here predicted, and that therefore *S* is probably not produced in the *E*-layer ; but a final decision must await further observations.

The discussion indicates that some eclipses are likely to be more favorable than others for the study of this question, and this should be borne in mind in planning magnetic observations during eclipses.

e) Lunar daily changes in geophysical elements.

The inter-relation between solar and lunar influences on geophysical phenomena imparts interest to a study of lunar tidal influences on the atmosphere, especially in connection

(1) « Proc. Inst. Radio Engineers », vol. 23, nr. 6 (1935).
(2) « Terr. Mag. », vol. 38 (1933), pp. 175-183.

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with the lunar daily magnetic variation. The writer has for many years been engaged in determining the lunar atmospheric tide at stations widely distributed over the earth. The following are some references to this work; further papers on the same subject have recently been communicated to the Royal Meteorological Society (1). The theory of the tide has a close relation with that of the solar diurnal oscillations of the atmosphere, which is still in a very difficult and unsatisfactory condition (2).

The lunar daily variation of temperature has also been detected at Batavia (3).

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(1) « Q. J. Roy. Met. Soc. », vol. 57 (1931), pp. 163-167. « Mem. Roy. Met. Soc. », vol. 4 (1932), pp. 21-25 and pp. 29-33; Vol. 60 (1934) pp. 23-28. « Proc. Roy. Soc. », A. No 872, vol. 151, pp. 105-117 (1935).

(2) « Gerlands Beiträge zur Geophys. », vol. 33 (1932) pp. 246-260; and TAYLOR G. I., « Mem. Roy. Met. Soc. », vol. 4 (1932) pp. 43-51.

(3) « Proc. Roy. Soc. », A, vol. 137 (1932), pp. 1-24; also « Mem. Roy. Met. Soc. », vol. 4 (1932), pp. 35-40.

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RESEARCHES OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM OF THE CARNEGIE INSTITUTION OF WASHINGTON BEARING ON SOLAR ACTIVITY AND THE EARTH'S MAGNETIC AND ELECTRIC FIELDS, 1932-1934

by

J. A. FLEMING.

Since the publication of the communication on the researches of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington bearing on solar activity and the earth's magnetic and electric fields in the III Report of the Commission, further work has been done as summarized below. Other researches of the Department not noted below are abstracted in this Report by L. V. BERKNER on *Variations of upper atmospheric ionization* (p. 101) and by A. G. MCNISH on *Solar activity and its relation to terrestrial-magnetic phenomena* (p. 76). For somewhat greater detail regarding the researches reference may be made to the annual Reports of the Director of the Department of Terrestrial Magnetism published in the Year Books of the Carnegie Institution of Washington.

The study of relations between solar activity and secular variation (see reference 12 given at end of article) was extended to include later data. The results confirm the apparent lag between solar activity, indicated by sunspot-numbers, and magnetic activity, indicated by the mean character-numbers, shown by previous discussions. The difference between annual changes derived from all-day means and selected-day means for data from the Cheltenham Magnetic Observatory showed

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that this difference fluctuates in agreement with sunspot-numbers, and it is significant that the same sort of lag exists here as is indicated by comparison with magnetic character-numbers.

The use of magnetic data for investigating radiation from the sun was discussed (1,2). The diurnal variations of terrestrial magnetism are caused primarily by electric phenomena in the highest parts of the earth's atmosphere. In magnetically quiet times, the state of ionization and other effects in the upper atmosphere are presumably caused by solar ultraviolet radiation, which is completely absorbed by the air before it reaches lower levels and hence can not be directly observed. Thus a close study of the magnetic diurnal-variations affords a possibility of obtaining observational information regarding this part of the solar spectrum and regarding, in particular, its variability. A scheme was outlined for a comprehensive representation of the system of the complex magnetic diurnal-variations on each single day, using a generalized harmonic dial; the variability of this system from day to day can be decomposed into a systematic world-wide part and into ephemeral changes, more or less regional. The systematic part can be used as an index for the effect and intensity of the solar agency in question.

The characteristic lag of terrestrial-magnetic activity behind solar activity occurring before a sunspot-minimum was confirmed (7). The study of the relations between various measures of terrestrial-magnetic activity and of solar activity was supplemented by using BRUNNER's series of monthly means of the profile-areas of the limb-prominences in the years 1910-32; this measure of solar activity was found only slightly, if at all, superior to the ordinary relative sunspot-numbers.

A discussion of magnetic correlations with solar conditions utilizing all available data was completed (2,5). It was concluded from the discussion that there must exist in the Sun's surface certain restricted areas (*M*-regions), the lifetimes of which are limited (up to a year) though generally longer than that of sunspots. They cause terrestrial-magnetic disturbances, probably by emitting well-defined corpuscular streams. These solar regions, as individuals, escape the usual astrophysical means of observation (visual, photographic, and spectrohe-

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lioscopic); they can as yet only be traced in terrestrial-magnetic activity. Terrestrial-magnetic records therefore obtain a purely astrophysical interest beyond their well-known geophysical aspect, namely, the indication of the times when the earth is actually under the influence of solar streams.

A test of the reliability of the 8-month and 11-month periodicities of the solar constant, described by C. G. ABBOT, was made by A. G. MCNISH using the harmonic-dial method of Bartels for the 88-month interval beginning September 1, 1923, over which these two periodicities are orthogonal. It was found that both periodicities may be represented to within the probable error of the smoothed values of a single trigonometric term. However, the uncertainty of the periodicities is so great that it warns against using them in attempting to predict magnetic or other terrestrial phenomena.

Pending the completion of the work on solar and lunar magnetic variations at Watheroo, 1919-30, according to the original scheme, similar work was begun for declination-data from Huancayo, 1922-30. Using the experience obtained in compiling the data for Watheroo, a new scheme was devised, starting with a simplified harmonic analysis for each individual day. In this way much material will be available for research on the variability of the solar diurnal variations, its relations to the lunar variations, and its bearing on the ionization in the high atmosphere (3). Special attention was devoted to discussions of the physics of the upper atmosphere and the variations of terrestrial magnetism since they yield the most reliable and detailed knowledge about solar and terrestrial relationships.

In a discussion by J. BARTELS of the tidal forces acting near the earth's surface a tabulation is given for all terms greater than 1/1000 of the main lunar term M_2. The physical significance of the various partial tides is illustrated and the origin of each partial tide is traced to characteristic features of the movements of the sun and moon. This discussion bears also on geophysical applications other than oceanic tides, such as atmospheric tides and terrestrial-magnetic variations, in which thermal and other changes with the period of a solar day are superposed on the gravitational tides. It is shown how diurnal changes with the period of a solar day having amplitudes changing with season lead, on formal harmonic

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analysis, to periods of a sidereal day which are sometimes mistaken for actual physical effects of cosmic origin.

In order to find an explanation of the abnormally large amplitudes of the magnetic diurnal-variations recorded at Huancayo magnetic Observatory, it would seem desirable to obtain approximate values of the lunar diurnal-variations as soon as the length of the series of observations would be sufficient. The hourly values there of declination in the years 1922-30 were therefore discussed, with the result that the lunar variation is found to be small, the ratio being solar : lunar = 15 : 1 ; an order normal for most observatories but markedly less than the ratio, namely, 3.8 : 1, derived from data for Batavia in approximately the same latitude as Huancayo. This appears to be a significant result, further discussion and conclusions regarding which must await reductions for the other seasons and especially reductions for horizontal intensity.

The annual variation of the mean magnetic vector at Watheroo was also investigated and a plan for the computation of the solar and lunar magnetic variations at Watheroo, 1919-30, was outlined. According to this scheme, days are grouped according to season, average sunspot-number for the month (three groups), and daily international magnetic character-figures (four groups). This choice of subdivisions is largely imposed by the necessity that the amount of data used in each group be sufficient to reduce accidental variation in the average.

A study of the variability of the quiet-day magnetic diurnal variation at Watheroo was made. Days with international character-figures 0.0 and 0.1 were selected. Two groups with high and low sunspot-activity were formed. The number of days available in each group during 1919-29 is 171 and 165, respectively. The seasonal change of the average diurnal variation, though small during the interval chosen (October 14 to February 28), is eliminated. The harmonic dials for the 24-hour sine-waves show that these very considerably even under very quiet conditions. An unexpected feature of the sine-waves on single days was found in a marked tendency to combine changes in phase and amplitude. This is expressed in the harmonic dials by a distinctive ellipticality in the distribution of the single factors. The ratio of the two axes

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of the « probable ellipse » is generally of the order 1.4 to 1. Attempts to interpret this phenomenon are postponed until more material has accrued, especially concerning the 12-hour wave.

A report (6) on methods of recording and measuring solar activity was prepared for the Lisbon Assembly of the International Union of Geodesy and Geophysics in September 1933, summarizing the measures, observations, and records of solar activity mainly used for comparison with geophysical phenomena and discussing their relative merits with regard to the study of correlations between solar and terrestrial phenomena.

Opportunity was taken during the total solar eclipse of August 31, 1932, to collect additional data (13) bearing on a possible effect upon the magnetic field due to the passage of the moon's shadow across the earth. The graphs drawn from the observations obtained at three stations showed a close identity of curves for all three and were similar in detail to magnetograms recorded at the Agincourt and Cheltenham observatories. An interesting feature was a small but distinct fluctuation which occurred immediately after totality at the field-stations and coincided quite exactly with the time the shadow crossed the New England coast-line and passed out over the sea. The occurrence of this small disturbance after many hours of normal diurnal-movement was quite startling and its coincidence with totality was suggestive of a possible connection, although it is recognized that the coincidence may have been entirely fortuitous.

Spectrohelioscopes after Hale's design, loaned by the Mount Wilson Observatory of the Carnegie Institution of Washington, were installed at the Watheroo and Huancayo observatories, and results are being regularly obtained according to schedule at these observatories. The results are communicated regularly to President L. D'AZAMBUJA of the International Astronomical Union's Commission N. 11, Meudon, France. The decision of the International Astronomical Union regarding the publication of the spectrohelioscopic observations will help to make the large material about solar phenomena provided by astrophysical observations available for geophysical research on solar and terrestrial relationships.

Investigations of various measures of magnetic activity were continued (11) and, in particular, of the measure adopted

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at Stockholm in 1930 by the International Association of Terrestrial Magnetism and Electricity: the so-called numerical magnetic character of days. The results indicate this measure is not altogether a satisfactory one for world-wide investigation of activity, as seasonal effects of varying magnitudes influence the values obtained by the method for stations differing in geomagnetic latitude.

A possible test for theories of magnetic diurnal-variations and magnetic storms was suggested (21). One of the three outstanding theories for diurnal variations requires a current-sheet in the lower regions of the ionosphere above which the normal magnetic diurnal-variations should be reversed. A crucial test would be a measurement of the magnetic changes above that region. Magneto-ionic double reflection of radio waves gives a measure of a magnetic field at a point at which reflection takes place. If a sufficiently accurate determination of changes of the magnetic field throughout the day can be accomplished by the study of radio-reflections, definite information on the theory would be forthcoming. Information on the location of the seat of the currents flowing during magnetic storms may be obtained in this manner.

An investigation was made of the « non-cyclic » change in horizontal intensity during international quiet days of the sunspot-maximum years 1919 and 1925-29 at the Watheroo magnetic Observatory. Upon plotting the change in gammas against the time in days, reckoned from the last preceding international disturbed day, a linear increase in the value of the horizontal intensity is indicated for quiet periods following disturbances at the Watheroo Magnetic Observatory of about 4 gammas per day. The mean value of the « non-cyclic » change for international quiet days at the same Observatory, as determined by end differences for the same period, is 5 gammas per day. Although the trend appears to be predominantly linear, there is a suggestion of a slightly greater slope for those days immediately succeeding a disturbance. There is reason to believe that time-intervals shorter than one day will reveal features of the recuperation of horizontal intensity which do not appear when the 24-hour interval is used.

O. H. GISH finds that changes in earth-currents, those in terrestrial magnetism, as well as those in polar lights, show a definite tendency to recur after a period of about 27 days,

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which is about the interval for the reappearance of a sunspot on the earthward side of the sun, and that the variations in earth-currents change from year to year in a manner similar to that of the magnetic variations, and both of these increase or decrease on the average as the sunspot-numbers increase or decrease.

A comparison of the records of earth-current potential at the Watheroo magnetic Observatory on disturbed and calm days shows a small but distinct and consistent difference in diurnal variation quite similar to that observed in magnetic records (22).

The earth-current records since March 1931 obtained at the Tucson magnetic Observatory in cooperation with the United States Coast and Geodetic Survey have been evaluated and the characteristics of diurnal variation and seasonal change appear to be quite well established by them. These earth-current records are of unusual interest because Tucson lies near the « zone of transition » where the diurnal variation of the northward magnetic component changes direction as one passes from the higher latitudes to the equatorial regions, so that these curves for summer and winter, respectively, are distinctly different. There is not found, however, at Tucson that persistence of a single type of diurnal variation throughout the year which has been observed at Watheroo and at Ebro, and also (although of a distinctly different type) at the equatorial station at Huancayo. The changes which occur are most readily appreciated when the diurnal-variation data are given in hodographs, the form of which changes markedly from month to month but repeats itself remarkably in the same months for different years. In view of the fidelity with which the divergent types of variation have repeated in the three years of measurement, they offer a promising basis for study in conjunction with the corresponding magnetic records to determine the relationship between the two phenomena.

Perhaps a most significant immediate advance at the Department bearing on cosmical relationships of terrestrial phenomena is that in the ionosphere research which was initiated by the Department in 1925. In its latest development, it appears the most promising of recent methods of approach and one greatly enhanced by the rapid progress in nuclear physics and in wave-propagation. It is now at the stage where

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continuous photographic records may be secured, manual observational methods meanwhile having shown fundamental results. This method appears also a sure means of obtaining definite information not only of the conditions of the, as yet, otherwise inaccessible regions above the earth's surface but of cosmical phenomena and of their relations to terrestrial ones. An understanding of the mechanism connecting the ionosphere and the external portion of the earth's surface must improve knowledge of the relation of cosmical radiations in the ionosphere to their images represented by the magnetic and electric phenomena at the earth's surface and below it.

It is observed from the nature of the data coming from Huancayo that there are certain occasional changes of the ionosphere, apparently not simply associated with other geophysical phenomena, which may be considered of major magnitude. It is interesting to note that such changes are in some ways equivalent to a shifting of an entire season for a few hours, suggesting a major solar effect in the ultra-violet spectrum. An important study under the automatic registration program will be the analysis of the recurrences of such effects.

A plan of observation in connection with the Pacific eclipse of June 8, 1937, for the study of changes of ionization of the rionosphee was prepared (10).

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REVIEW OF CERTAIN CONTRIBUTIONS TO COSMIC ELECTRICITY AND MAGNETISM

by

ROSS GUNN.

This review is a continuation of that published in the III Report and is designed to bring it up to date.

Earlier studies (see references 1, 2, 3 at end of article) showed that the observed remarkable characteristics of the sun's anomalous rotation can be described if the sun maintains an electric field throughout its atmosphere that is radially inward at the equator, approximates to 0.015 volt per centimeter in the reversing layer, and decreases with altitude much as the magnetic field is observed to decrease. Observation indicates that the magnitude of the field also varies with solar activity. Calculations of the electrical state show that the free positive charge in the sun's atmosphere in regions that may be observed (that is, at levels where the magnetic field is less than 100 gauss) approximates 3×10^7 e.m.u (4). and a neutralizing negative charge of equal magnitude must exist in regions immediately below the reversing layer (12). Further, the lower reversing layer is negative with respect to free space by about 10^6 volts (4).

Subsequent papers considered the relation of the electric field to the departures of the sun's radiation from that of a black body and to the support of the chromosphere (5). It is shown that the forces on ions in regions of sufficiently low pressure are such as to contribute to the observed effects. The investigation of the systematic atmospheric motions and the impressed electric field are shown to lead to the prediction that bright-line spectra and rapid apparent axial rotations

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should exist simultaneously in magnetized stars (6). STRUVE has established such a correlation by his observations on early type stars (7).

A complete theory of the origin and maintenance of the sun's electric field has been worked out which supports the inferences drawn from the observational material in every important respect (8). The conduction and replenishing current-densities are calculated and it is shown that the latter may actually exceed the former unless dissipation-processes raise the effective electron temperature of the selected region. The mechanism of replenishment depends on the known fact that electrons recombine with positive ions more readily when they move slowly than when they move rapidly. The influence of the electric field in systematically modifying the electron-velocities and recombination-probabilities results in a general migration of electrons against the electric field. It is shown that ionization and recombination are sufficiently rapid in the sun to maintain the required electric field. Due to the different types of recombination the electrical equilibrium in the chromosphere is radically different from that in the reversing layer. It is shown that the equilibrium in the chromosphere is such that the effective electron-temperature must be something like 25,000°. Such effective temperatures will account for the excitation of the ionized helium line $\lambda 4686$ and for very low pressure gradients in the chromosphere (8). Thus it appears that the chromosphere may approximately be in ordinary gravitational equilibrium. This latter conclusion is based on the well-known solar ion-density estimates of RUSSELL and of MENZEL. If the ion-densities are appreciably less than their values, then the electric and magnetic forces on the ions will determine the stability (5).

The magnetic forces acting on the atmospheric ions of a rapidly rotating star are shown to prevent the loss of the star's atmosphere and angular momentum (9) and it may evolve by fission into a multiple star or two independent stars with systems of satellites (10).

An earlier paper made several suggestions as to the origin and maintenance of the solar and terrestrial permanent magnetic field and attributed the field to drift currents arising from crossed electric and magnetic fields (11). It was suggested that the required outward radial electric field might arise

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from the gravitational separation of charge, difference in ion-concentration, or from radial temperature-gradients. It may be shown on thermodynamic grounds that only the last possibility is now acceptable and this requires that the internal temperatures of the sun and earth be high compared to their surface-temperatures. The current-densities produced by this Nernst effect seem adequate to produce the observed field.

It has often been suggested that the aurora is produced by ions emitted from the sun, and because a hydrogen ion falling through the calculated sun's electric field would emerge with about the proper energy to plunge into the earth's atmosphere in auroral zones it seemed of interest to examine the processes of emission. The investigation has shown that only within a sunspot are conditions such that a negative ion can traverse the solar atmosphere and emerge with an energy of some 10^6 electron volts (12). An electron or negative ion which succeeds in traversing the sun's atmosphere emerges at high speed and attracts to itself a neutralizing positive ion, forming a loosely bound ion-pair and finally both ions leave the sun with identical velocities. It is noted that similar processes taking place in magnetized and very hot stars could produce ion-pairs with cosmic-ray energies. This conclusion is well supported by the theoretical investigation of the mode of maintenance of stellar electric fields (8).

It has been pointed out that the observed state of rest of ionized calcium clouds in interstellar space guarantees that all such regions are field free and electrically neutral to a high degree of approximation (12, 13). Clear-cut arguments based on this observed fact show that all ions traversing space are in the nature of ion-pairs (statistically) and that both components of the pair must move with the same velocity. Thus the energy of the heavy ions is always far greater than the usually accompanying electron (12, 13). It is shown that the properties of such ion-pairs plunging into the earth's atmosphere could account for the observed properties of the aurora and for the azimuthal asymmetry of cosmic rays (13). It has been further pointed out that the small diurnal variation of cosmic-ray intensity can be accounted for by the variations of ionization in the earth's diamagnetic layer (14).

Certain problems of terrestrial atmospheric electricity and thunder-storms have also been investigated (15, 16).

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SUR L'INTERVALLE DE TEMPS ENTRE LES PHÉNOMÈNES SOLAIRES ET LES PERTURBATIONS MAGNÉTIQUES TERRESTRES

par

CH. MAURAIN.

J'ai étudié ce sujet en 1926 par une méthode statistique(1). J'ai montré, comme résultat d'une étude portant sur toutes les journées à perturbation magnétique d'une période de 41 années, que l'activité solaire évaluée numériquement pour les journées voisines d'une perturbation magnétique passe, en moyenne, par un maximum environ deux jours et demi avant les perturbations magnétiques. Il semble qu'on en puisse conclure qu'il existe, au moins en de nombreux cas, une liaison entre l'activité solaire et les perturbations magnétiques avec un décalage de temps de deux jours et demi en moyenne. Ce décalage est d'ailleurs variable ; en prenant, parmi ces 41 années, 10 années qui correspondent à des époques de faible activité solaire, on trouve comme décalage moyen 3 jours 3/4 environ. Dans ce travail, j'ai pris pour caractériser l'activité solaire les nombres dits de WOLF et WOLFER.

Depuis, l'observation du soleil s'est étendue et perfectionnée, et diverses publications nouvelles facilitent l'emploi systématique de la méthode consistant à examiner les cas

(1) « Comptes Rendus de l'Académie des Sciences de Paris », t. 182 (1926), p. 1550 ; « Annales de l'Istitut de Physique du Globe de l'Université de Paris », t. 5 (1927), p. 86.

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particuliers et à rechercher l'intervalle de temps existant entre un phénomène solaire déterminé et une perturbation magnétique qui paraît lui correspondre. On a signalé bien souvent de tels intervalles de temps. J'ai examiné à ce point de vue tous les passages de taches ou groupes de taches importants des années 1930, 1931 et 1932, au nombre de 34, et aussi quelques cas correspondant à des phénomènes solaires brillants qui se sont manifestés au voisinage du méridien central du soleil (1).

Sur 34 cas de passage d'une tache ou groupe de taches importants au méridien central du soleil, 24 semblent permettre une évaluation d'un intervalle de temps entre le passage et une perturbation magnétique consécutive. Ces intervalles de temps sont, en heures : 23,5 - 29 - 33 - 33 - 35 - 38 - 39 - 40 - 42 - 42,5 - 46 - 57 - 58 - 61 - 64 - 66 - 72 - 80 - 81 - 81 - 94 - 102,5 - 104 - 116,5, dont la moyenne est 60 heures. Cette concordance numérique avec le résultat que j'avais obtenu par une méthode statistique est évidemment fortuite ; elle montre seulement que les évaluations faites par ces deux méthodes, statistique et individuelle, sont du même ordre de grandeur. On doit remarquer que les perturbations magnétiques dont il s'agit ici sont de diverses intensités, certaines pas très fortes.

L'examen de quelques cas de phénomènes solaires brillants au voisinage du méridien central du soleil conduit à un intervalle de temps moyen d'environ 40 heures.

Dans le mémoire des Annales cité ci-dessus, je cite divers mémoires récents sur ce sujet, en particulier de : G. ABETTI (1927) (2), J. M. STAGG (1928), W. M. H. GREAVES et H. W. NEWTON (1928), G. E. HALE (1931), dans lesquels sont données des évaluations de tels intervalles de temps.

Il semble qu'on puisse admettre, comme conclusion de ces études de genres divers portant sur de très nombreux cas, la généralité de l'existence d'un intervalle de temps entre des phénomènes solaires caractérisés de différentes manières et des

(1) « Comptes Rendus de l'Acad. des Sc. de Paris », t. 196 (1933), p. 1182 ; « Annales de l'Institut de Physique du Globe », t. 12 (1934), p. 63.

(2) G. ABETTI, *Sulle relazioni fra le eruzioni solari e le tempeste magnetiche terrestri*, « Rend. R. Accademia Lincei », vol. V, pag. 721, maggio 1927.

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perturbations du champ magnétique terrestre, et que cet intervalle de temps est variable.

On cite parfois des cas, correspondant à des observations de CARRINGTON, d'YOUNG et de TROUVELOT, dans lesquels il y aurait eu, à quelques minutes près, simultaneité entre les deux phénomènes. Or HALE, dans le mémoire que je rappelle ci-dessus, a discuté le cas Carrington, et il retient ce cas comme un de ceux où un intervalle de temps est le mieux défini (17 heures et demie). Examinant d'après les sources le cas dit de Trouvelot, je n'ai trouvé aucune indication de Trouvelot en ce sens, et les magnétographes de l'Observatoire du Parc Saint Maur ne présentent pas de perturbations à l'heure de l'observation solaire de Trouvelot. Quant au cas d'Young, il a été étudié autrefois par J. BOSLER, et les graphiques reproduits par Bosler manifestent une coïncidence frappante. C'est, à ma connaissance, le seul cas pour lequel on peut retenir une coïncidence, qui n'implique pas nécessairement une relation de cause à effet entre les deux phénomènes.

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SOLAR ACTIVITY AND ITS RELATION TO TERRESTRIAL-MAGNETIC PHENOMENA

by

A. G. McNish.

Magnetic secular variation. — Further studies of possible solar effects on the secular variation of the earth's magnetic field initiated by Fisk (see reference 1 cited at end of article) have led to the conclusion that the principal manifestations are due to the accumulation of post-perturbation effects in the horizontal and vertical components of the earth's magnetic field during years of high solar activity (2). An outstanding feature of magnetic storms is a decrease in the horizontal intensity and a concomitant increase in the vertical intensity in middle latitudes. This is evidenced in the algebraic signs of the differences, quiet days minus disturbed days, which are positive in horizontal intensity and negative in vertical intensity. The prevalence of magnetic storms during years of high solar activity accounts for the presence of an 11-year cycle in the secular changes in the magnetic intensities. To reveal these effects second differences of the annual values of the intensity-components for all days and of the annual values of the interdiurnal-variability measure (3) of magnetic activity were formed. The values of the correlation-coefficients of these second differences for various observatories are shown in Table I.

Although the coefficients are undoubtedly due to post-perturbation phenomena, the facts that similar coefficients are obtained for the ten most quiet days at Honolulu, Tucson, Cheltenham, and Sitka, which days are largely free of post-

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TABLE 1.

Correlation-coefficients, second differences of annual values horizontal and vertical intensities and of magnetic activity.

Observatory	Geomagnetic latitude	Correlation-coefficients	
		Horizontal intensity	Vertical intensity
Bombay	9°.5 N	— 0.56	+ 0.17
Batavia	18°.0 S	— 0.30	.....
Honolulu	21°.0 N	— 0.74	+ 0.13
Tucson	40°.4 N	— 0.39	+ 0.17
Cheltenham	50°.1 N	— 0.65	— 0.12
Potsdam-Seddin	52°.5 N	— 0.38	+ 0.34
Sitka	60°.0 N	— 0.21	+ 0.24

perturbation effects, and that the differences between quiet and disturbed days in vertical intensity at Sitka are positive instead of negative indicate strongly that the 11-year cycle in secular variation is due in part to an actual 11-year variation in that portion of the earth's field which is of external origin. The absence of suitable data from high-latitude stations prevents definite conclusions of this important possibility of a solar-terrestrial relationship.

Sudden commencements. — Abrupt changes in the earth's magnetism, known as sudden commencements because they are frequently the precursors of magnetic storms, supply evidence of the effect of the sun on the earth's magnetism. Sudden commencements, 151 in number, recorded at the Watheroo Magnetic Observatory of the Department of Terrestrial Magnetism during the years 1919-30, clearly demonstrate (see Figs. 1, 2, and 3) a daily, seasonal, and 11-year distribution (4). The usual time for the occurrence of these sudden commencements is the afternoon, local time, when the Observatory is « behind » the earth in its orbital motion. The view that sudden commencements are caused by streams of solar corpuscles which overtake the earth is supported

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by this fact. It is also noted that a larger number of sudden commencements occur during the local summer than during the local winter.

The association of sudden commencements with magnetic storms leads to the expectation that they will be more fre-

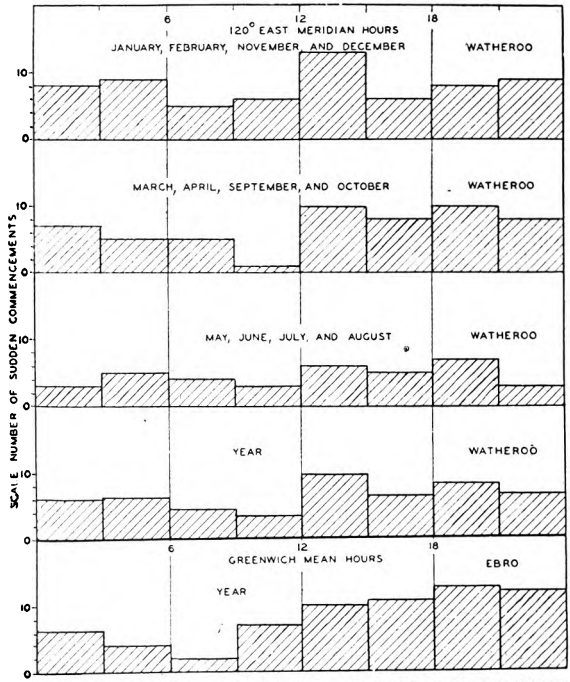

FIG. 1—DIURNAL VARIATION IN NUMBER OF SUDDEN COMMENCEMENTS AT WATHEROO (1919–1930 ALL TYPES) FOR SEASONS AND YEAR AND AT EBRO (1905–1931 RODÉS A-TYPE) FOR YEAR.

quent during years of high solar activity. This has been found to be the case. RODÉS (5), who studied sudden commencements recorded at the Ebro Observatory from 1905 to 1931, arrived at the same conclusions. Since Ebro and Watheroo are nearly antipodal, the two independent findings constitute an important verification of facts, particularly those relating to seasonal and diurnal distributions. The interpretation to be made

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of these facts is that sudden commencements are due to a complex of at least two causes : one giving rise to the 11-year distribution, which is associated with the sunspot-cycle, and another giving rise to the seasonal and diurnal distribution, which is due to the earth's position and orientation relative to the sun.

Magnetic diurnal-variation. — Thirteen years of magnetic observations at the Huancayo Magnetic Observatory of the

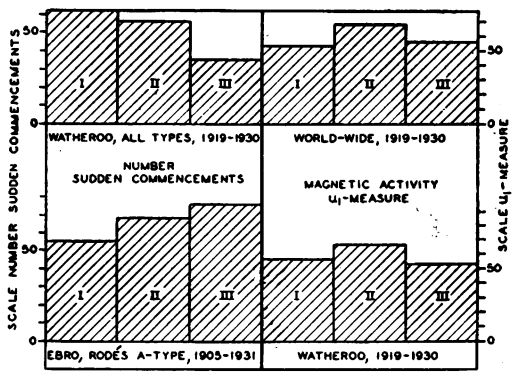

FIG. 2—SEASONAL VARIATION IN NUMBER OF SUDDEN COMMENCEMENTS AND IN u_1-MEASURE OF MAGNETIC ACTIVITY

I = JANUARY, FEBRUARY, NOVEMBER, AND DECEMBER; II = MARCH, APRIL, SEPTEMBER, AND OCTOBER; III = MAY, JUNE, JULY, AND AUGUST

Department of Terrestrial Magnetism of the Carnegie Institution of Washington, established in 1922, have revealed unusual features of the magnetic solar-diurnal variations owing to the proximity of this station to the magnetic equator.

Besides unexpectedly large variations in the horizontal component of magnetic force (6) which have compelled the recognition of pronounced local characteristics in the system of external causes to which the variations are due, irregular features in the vertical-intensity variations are of particular interest. Their seasonal changes during the past 13 years show that in general the variation is of the northern type during northern summer and of the southern type during southern summer, indicating the increased effect of solar ra-

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diation on the ionosphere north and south of the equator as the sun's zenith-angle decreases. Individual days exhibit a more striking phenomenon, the variation frequently changing from the northern type to the southern type, and viceversa, within 24 hours.

Assuming that the diurnal variations are due to electric currents flowing in the ionosphere, a reasonable explanation

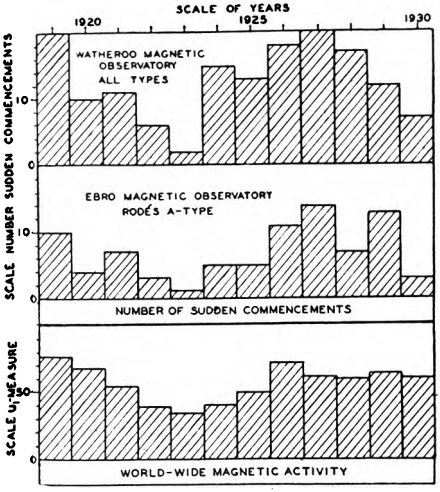

FIG.3— SECULAR VARIATION IN NUMBER OF SUDDEN COMMENCEMENTS AT WATHEROO AND AT EBRO AND OF WORLD-WIDE u_1-MEASURE OF MAGNETIC ACTIVITY

of this variability is that the conductivity of the upper regions of the atmosphere changes with seasons so that the northern or southern current-system increases its area and sweeps over the Observatory when the conductivity increases. The shift between northern and southern types of vertical-intensity variations indicates that the conductivity in the northern and southern hemispheres varies as much from day to day as it does, on the average, from season to season. Since, regardless of any theory as to the cause of the magnetic solar-diurnal variations, it is necessary to attribute them to an effect of the sun on the atmosphere, it must be recognized

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that the effect of the sun north and south of the equator must be quite different, relatively, on different days.

When observations at Huancayo were begun, the characteristic variations in vertical intensity during the southern summer tended toward a southern type. During northern summer the variations in vertical intensity exhibited no definite characteristic. By a gradual transition through the years, the variations during the northern summer became of a distinct northern type. Associated with this trend is the fact that Huancayo, although in the southern geographic hemisphere, was on the magnetic equator just prior to the beginning of the Observatory's registrations and now, owing to a shift of the magnetic equator, it is about 2° north of it.

It seems likely that the Huancayo vertical-intensity variations will be of a predominatingly northern type now for many years to come. This change in type of the vertical-intensity variations at Huancayo definitely proves what has been believed for some time that the general magnetic field of the earth plays an essential part in causing the magnetic diurnal-variations. Although the sun is fundamental in causing the variations, it does so only in conjunction with the earth's general magnetic field and not through its action alone as has been suggested in some of the older and long-since discarded theories.

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(1) Internat. Res. Council, « Third Rep. Comm. Solar. Terr. Relationships », 52-59 (1931).

(2) BARTELS J., « Terr. Mag. », v. 37, 1-52 (1932).

(3) MCNISH A. G., « Trans. Amer. Geophys. Union », 14th annual meeting, 139-144 (1933) ; « Trans. Amer. Geophys. Union, » 15th annual meeting, I, 175-176 (1934).

(4) MCNISH A. G., « C. R. Assemblée de Lisbonne », septembre 1933 ; « Union Géod. Géophys. Internat. », « Ass. Mag. Electr. Terr. », Bull. N. 9, 234-238 and 238-240 (1934).

(5) « Terr. Mag. », v. 37, 273-277 (1932).

(6) JOHNSTON H. F. et MCNISH A. G., « C. R. Cong. Internat. d'Electricité », Paris, v. 12, 41-52 (1932).

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PROMINENCES, THE ULTRA-VIOLET RADIATION OF THE SUN AND THE DIURNAL CHANGE OF TERRESTRIAL MAGNETISM

by

E. J. Perepelkin.

Beginning with 1928 the prominence spectra have been systematically photographed with the three-prism spectrograph attached to 30-inch refractor of Poulkovo Observatory almost every summer. At the present time the Observatory possesses a collection of nearly two and a half thousands spectrograms. The study of this material has clearly shown, that the ratio i of intensities of H_ε hydrogen and H ionized calcium lines varies in large limits-from 0.1 to more than 1 (1). This ratio appears to be correlated with the observed Doppler shift of Ca lines as well as with height above the solar edge at which the prominence spectrum was obtained. The examination of spectra, showing Doppler shift less than 3 km. per sec. and obtained at a height of $8''-14''$, has well demonstrated this ratio decreases toward the minimum of solar activity and increases again recently. The mean value of i is practically the same for various heliographic latitudes, but the individual intensities i varie from prominence to prominence, what allows us to think that the causes of this changes should not be looked for at the sun as a whole.

(1) The ratio i of intensities of $H\varepsilon$ and H lines was determined from eye estimates on a ten step scale. These estimates were then photometrically calibrated («Poulkovo Obs. Circ.», nr. 9, 1933). In order to obtain real relative intensities of $H\varepsilon$ and H lines the mentioned values of i should be multiplied by 0.4.

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These observations may be explained by supposing the existence on the solar surface of spots rich in intense extreme ultra-violet radiation or ejecting sufficient fast particles (electrons). In both cases the subordinate H_ε line with all Balmer series should increase in intensities more than the resonance H line. Brief considerations show, that i should increase with the strenght of mentioned agents. We suppose here the constancy of relative concentrations of hydrogen and calcium atoms, which seems as we shall see below to be natural. It is well known that the intensity of lower parts of solar corona consisting of ejected electrons is considerably variing with the heliographic latitude. Therefore the observed constancy with latitude of i confirms that the high excitation of H_ε is not due to the fast particles ejected by the solar surface. It seems that the remaining hypothesis of spots rich in intense u.-v. radiation with $\lambda < 0.1\mu$ can better explain the excitation of Balmer series.

This results may be of interest for the study of ionosphere, the formation of which is principally due to the action of u.-v. radiation of the sun with λ 0.05-0.10μ (as it was shown by the study of solar eclipse 1932). The great number of spots rich in u.-v. radiation would give on the average a large value of i; and simultaneously increase the density of electrically charged layer produces the diurnal changes in terrestrial magnetism, the range of these changes being at first approximation proportional to the density of the mentioned layer and also to the value of i. A good agreement between the variations of i from summer to summer and those of declination was stated by P. GUSSEV. In reality the electrically charged layer of ionosphere is formed also by some non solar agents. On the other hand the measured range of the diurnal change of terrestrial magnetism is somewhat enlarged by the influence of magnetic storms. The value i is also some influenced by the systematic errors of determinations. Thus the above range A should be of the type:

$$A = a \times bi, \text{ where } a \text{ and } b \text{ are two constants.}$$

In the following table are given: the year and months of observations, the number of days of prominence observations, the mean value of i for the period, the measured value W_D of diurnal declination change in Sloutzk (Pavlovsk), pro-

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portional to range A and expressed in $\varepsilon = 1.72 \times 10^{21}$ ergs units (Bauer), the computed value W_D and the sunspot relative number r for the same period. For the computation of W_D it has been used a least-squares solution, which give (with p. e.):

$$W_D = (5.0 + 21.8i)\varepsilon$$
$$\pm .9 \pm 2.0$$

The following table is illustrated by fig. 1.

Year	Period of observation	No. of observ. days	i	W_D		r
				measures	computed	
1928	July	13	0.58	18.6ε	17.7ε	98
1929	April-August	72	39	13.1	13.5	64
1930	May-August	40	42	14.7	14.2	28
1931	» »	41	34	11.6	12.4	18
1933	» »	40	26	11.2	10.7	3
1934	May-July	23	23	10.6	10.0	12
1935	May-June	29	35	12.6	12.6	36

It is interesting to note that the correlation coefficient between i and the measured value of W_D is 0.98, being larger than that between r and W_D. We have a new index of solar activity which possesses a definite physical sense, what is the most valuable. Unfortunately this new index corresponds only to the extreme parts of sun disc.

Recently the decrement of Balmer series of hydrogen spectrum of prominences was investigated at Poulkovo. One undertook accurate spectrophotometrical intensity determinations of lines H_β, H_γ, H_δ and H_ε of prominence spectrum in different parts of prominences. These determinations showed a good correlation between the relative intensities of these lines and the ratio of intensities i of H_ε and H lines at the basis of prominences. It was found that the relative intensities of violet lines of Balmer series increases with i. The investigation of 7 prominences with a large number of deter-

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minations for several parts of these prominences on the average gave:

$$i = 0.15; \frac{H_\gamma}{H_\beta} = 0.37; \frac{H_\delta}{H_\beta} = 0.15; \frac{H_\varepsilon}{H_\beta} = 0.10;$$
$$i = 0.70; \quad » \quad = 0.45; \quad » \quad = 0.26; \quad » \quad = 0.20.$$

This makes undoubtful the connection between index i and the u.-v. radiation of individual areas of solar surface.

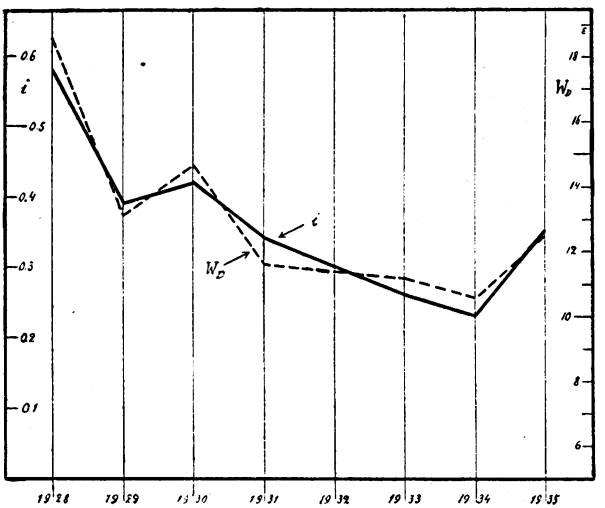

Fig. 1.

The dependence between the relative intensities of Balmer series and the u.-v. radiation of these individual spots was studied in theory by V. VIASANITZYN. He suggested the existence of the mechanism of cyclic transitions adopting 8 atomic states, the ionisation level included. For his investigation he selected the point of prominence located 20.000 km. high above the photosphere and studied a series solar radiation of different types. In the first approximation the prominence appeared to be transparent. It was assumed in all cases that the photosphere, as observed from the above point of prominence at solid angle $\omega_{ph} = 0.4$ and radiating as a black body with

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the temperature $T_{ph} = 6000^o$, illuminates the atoms of prominence. In four cases it was surmised that on the photosphere there exist some small spots rich in extreme u.-v. radiation, equivalent to the black body radiation at the temperature T_s. The area of these spots was adopted 1 and 100 square seconds of arc. These can be observed from the selected point of prominence at solid angle ω_s. The results of computations are given in the following table (In all cases $T_{ph} = 6000^o$, $\omega_{ph} = 0.4$):

		$\frac{H_\gamma}{H_\beta}$	$\frac{H_\delta}{H_\beta}$	$\frac{H_\varepsilon}{H_\beta}$
$T_s = 6000^o$,	$\omega_s = 0$	$= 0.26$	$= 0.11$	$= 0.05$
$T_s = 10000^o$	$\omega_s = 10^{-4}$	0.32	0.15	0.08
	$\omega_s = 10^{-2}$	0.33	0.16	0.08
$T_s = 20000^o$	$\omega_s = 10^{-4}$	0.41	0.22	0.12
	$\omega_s = 10^{-2}$	0.41	0.22	0.12

As seen from the table, the relative intensity of prominence spectrum for spots of the photosphere having the area larger than 1 sq. sec. depend only on their « effective temperature » T_s increasing with it. A single *granula* rich in ultra-violet radiation can produce an appreciable change in the decrement of the spectral line series of the prominence located above this *granula* and increase index i.

This result by VIASANITZYN does theoretically confirm the earlier conclusions. However these results have shown the probable impossibility of finding in a direct way the spots of the photosphere with abnormally intense ultra-violet radiation, as their area may prove to be to small.

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AURORES POLAIRES.

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INVESTIGATIONS ON AURORA AT THE AURORAL OBSERVATORY, TROMSÖ, NORWAY

by

LEIV HARANG.

1. A considerable number of parallactic photos of aurorae taken from two stations lying 43 km. apart have been made during the last years. The ranges of heigths of the normal green-yellow coloured aurorae are well known from the numerous pairs of parallactic photos taken during the last decades in Norway. During the last years special attention have been paid to the appearance of aurorae of unusual colour or forms. In this connection we will mention an interesting display of an auroral arc having a dark crimson coloured lower edge, which was photographed parallactically in March 1932 by Dr. W. BAUER and the author by means of two film-cameras. The heigths of this red-coloured arc showed to have the unusual low values of 70-75 km. above the earth's surface. Fig. 1 shows the heigths (B) compared with the heigths of normal yellowgreen arcs (A) and (C) (1).

2. To investigate the distribution of light in the different parts of the auroral spectrum in the individual auroral forms, simultaneous filter-photos in different spectral regions have been taken. By using suitable filters, photos in infrared, red, green, blue and ultraviolet have been taken. Fig. 2 shows the distribution of light in green (auroral green line 5577 A)

(1) HARANG L. and BAUER W., « Gerlands Beiträge zur Geophysik », Bd. 37 (1932), p. 109 ; « Nature », 130 (1932), p. 764.

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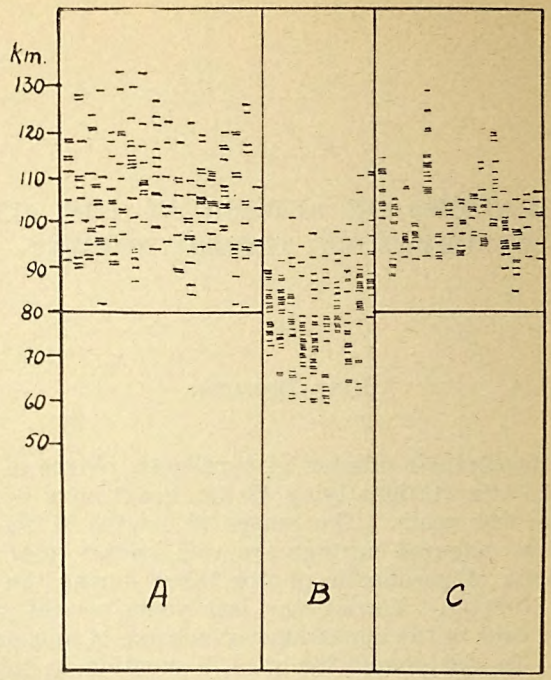

Fig. 1.

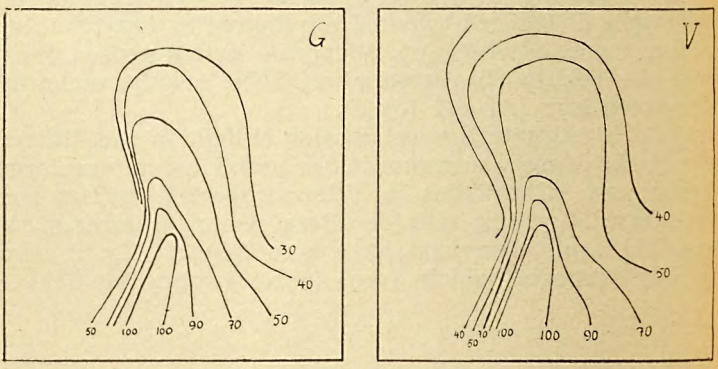

Fig. 2.

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and in blue (nitrogen bands 4708, 4278 and 3914 A) of an auroral drapery measured by a microphotometer (1).

3. During the last two winters work has been devoted to trials to obtain interferometric pictures by Fabry-Perot etalons of red lines in the auroral spectrum. According to McLENNAN's theory the two auroral lines 6360 and 6300 A may be classified as oxygen lines originating from the transitions $(^4S)2s^22p^4\ ^3P_1$—$(^2D)2s^22p^4\ ^1D_2$ and $(^4S)\ 2s^22p^4\ ^3P_2$—$(^2D)2s^22p^4\ ^1D_2$. Interferometric pictures have been obtained of the stronger one of these two lines, 6300 A, showing that the line has the structure of an atomic line. A preliminary account of the subject has appeared (2).

(1) HARANG L., « Zs. f. Geophysik », (1931), p. 324; HARANG L., « Geofysiske Publikasjoner », vol. X, n. 8 (1934), Oslo.

(2) HARANG L. and VEGARD L., « Nature », 135 (1935), p. 542.

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THE PRODUCTION OF THE AURORAL SPECTRUM

by

J. KAPLAN.

The purpose of the studies of the auroral spectrum can be summed up by quoting from a paper by MARIS and HULBURT (1) who say that a complete theory of auroras « will require among other things complete knowledge of the energy levels, metastable states, and transition probabilities of the atmospheric atoms and molecules, as well as of the exact process which give rise to the aurora light ».

A brief description of the auroral spectrum will be given before the recent experiments or the production of the auroral spectrum or the laboratory are described. The auroral spectrum is emitted almost entirely by nitrogen and oxygen. The oxygen is responsible for the well known green line λ 5577.35 and for the two red lines λ 6300 and λ 6364. The nitrogen part of the auroral spectrum consists principally of the first-negative bands which are emitted by the nitrogen molecule-ion, the second-positive bands, the first-positive and the recently discovered VEGARD-KAPLAN system (2), all emitted by the unionized nitrogen molecule. The Vegard-Kaplan bands were produced in gaseous nitrogen for the first time in the course of the experiments to be described here.

Having described the auroral spectrum, let us see why its components are such strange companions. The auroral

(1) MARIS and HULBURT, « Phys. Rev. », 33, 412 (1929).
(2) KAPLAN, « Phys. Rev. », 45, 675 (1934).

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green line and the two red lines are the only ones due to oxygen, that are present in the auroral spectrum. This is in itself a strange phenomenon, since it is only under very unusual conditions that the spectrum of an atom is limited to a few lines as is the case in the aurora. Now the first negative bands of nitrogen are easily obtained in electrical discharges at the pressures that exist in the upper atmosphere, but the spectrum of the neutral molecule is not readily obtained at those pressures. That spectrum is characteristic of discharges at higher pressures. Furthermore, the nature of excitation of the first positive bands which occurs in the aurora, does not agree with the excitation in the electrical discharge. It is impossible to simply pass a discharge through nitrogen at very low pressures and obtain the nitrogen part of the auroral spectrum, or to do the same for a nitrogen-oxygen mixture and obtain the entire auroral spectrum.

Still another aspect of the problem should be described. The auroral spectrum contains some weak and yet extremely important radiations which fall in the green, yellow, red and infra-red and these have been difficult to identify with a great degree of certainty. The failure to do so has been due partly to the difficulty of obtaining good spectra and partly to overlapping of spectra. One of the most striking results of the present experiments is the positive identification of some of these troublesome auroral radiations.

There is one important reason why the study of the nitrogen afterglow was chosen as the line of attack on the problem of the aurora. While studying the modification of the spectrum of active nitrogen by oxygen, a line was noticed in the spectrum of the afterglow which appeared only when oxygen was added, and only when its concentration was very small. This line turned out to be the aurora green line λ 5577.35, and it was the only oxygen line to appear on the plate. Since this is its most striking characteristic in the auroral spectrum, the connection between the latter and active nitrogen was immediately suggested.

In the last paragraph a reason was given why the study of active nitrogen seemed to be the most promising line of attack on the problem of reproducing the auroral spectrum. This also seemed to be an attractive problem because it not only promised a solution for the auroral and active-nitrogen

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problems, but it also gave promise of yielding new results with regard to the nitrogen molecule. This last promise has been well kept since five new band-systems of nitrogen have been discovered during the course of these experiments.

Active nitrogen is usually produced by passing a condensed discharge through nitrogen at about 0,5 mm. pressure. It has a most unusual spectrum which consists of selected members of the first-positive bands of nitrogen. The selected bands are those which originate on the tenth, eleventh and twelfth vibrational levels of the so-called $B^3\pi$ state of nitrogen. No other very strong bands have been observed in the spectrum of active nitrogen which is produced this way. Bands originating on the sixth vibrational level are stronger than those originating on levels in its immediate vicinity, but this maximum is much weaker than the one which is due to the eleventh level.

Several years ago the writer discovered a strong afterglow of nitrogen which was produced by means of an uncondensed discharge in nitrogen at pressures around 10 mm. (1). The spectrum of the discharge in which this afterglow was produced was quite remarkable. Instead of the first-positive bands and the second-positive bands, this spectrum consisted of the first-negative bands and the first-positive bands ; and those first-positive bands which originated on very high vibrational levels were greatly enhanced in comparison with their appearance elsewhere. This change in the spectrum from that normally observed as well as the change to this auroral combination of the first-negative and first-positive bands, became more thorough the stronger the afterglow. In the ultraviolet this discharge emitted a new system of bands which was identical with a system observed by VEGARD in the luminescence of solid nitrogen, (2) and three members of which agreed closely with three very strong auroral radiations. This system had never been observed in gaseous nitrogen before the present experiments.

The tube in which all the above phenomena occurred showed rather remarkable color-changes as the conditions of excita-

(1) KAPLAN, « Phys. Rev. », 45, 671 (1934).

(2) VEGARD, « Skrifter Utgitt av det Noerske Videnskamps-Akad. », Oslo, I. Mat. Naturv. Klasse, 1930, n. 2.

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tion varied. Two stages were particularly prominent, a green stage at low current and a blue stage at high current. The greenish-white color in the first stage and the blue-white color of the second stage correspond very closely with the most common auroral colors.

The afterglow which accompanies the green stage is so different than that which accompanies a condensed discharge, that it really should be considered to be a new afterglow in nitrogen. This is also true for the other stages of the discharge, but to a lesser extent. In fact, the higher the current through the tube the more like the normal afterglow does this afterglow become.

The most prominent bands in the spectrum of the afterglow, when the tube is operated in the green stage, are the first negative bands of N_2^+ and those first-positive bands which originate on the $V' = 15$-, 16-, 17-. 18- and 19- levels. The spectrum of the discharge itself resembles that of the afterglow very remarkably. The afterglow spectrum is more like that of the aurora than is the discharge spectrum. More will be said about this later.

VEGARD (1) has reported first-positive bands in the aurora with wavelengths 5001A and 5241A, and has interpreted these as the first positive bands (15, 10) and (16, 11). These bands form a prominent feature of the new afterglow and their presence in the afterglow in the company of the negative bands not only confirms the identification proposed by Vegard, but it justifies the claim that the nitrogen part of the auroral spectrum has been reproduced in the laboratory.

A word should be added here as to the connection between the first-positive bands in this new afterglow and the spectrum of the luminescence of solid nitrogen. Four prominent bands or sets of bands in the luminescence of solid nitrogen have been observed in the region where first-positive bands, which originate on high vibrational levels, fall. The writer has previously identified these as belonging to the first-positive system and he has also pointed out the remarkable agreement between them and auroral radiations (2). In the

(1) VEGARD, « Geofysiske Publikasjoner », vol. X, n. 4 Utgitt av det Noerske Videnskamps-Akad., Oslo.

(2) KAPLAN, « Phys. Rev. », 42, 86 (1932).

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present afterglow the first positive bands are so like the N_1, N_2, N_3, and N_4 bands of the solid luminescence that this resemblance justifies the identification of these bands as well as the idea of a resemblance between the solid luminescence and the auroral spectrum. It must be remarked here that Vegard has often pointed out this resemblance but on far less certain evidence than that presented here.

The spectrum of the afterglow in the ultraviolet shows several features which are absent in the case of the afterglow produced by condensed discharges. In the new afterglow there is a large amount of ultraviolet whereas in the older modification the ultraviolet is completely devoid of radiation. The Vegard-Kaplan bands, the second-positive and the first negative bands all appear in the ultraviolet glow. These three systems appear also in the ultraviolet part of the auroral spectrum. The Vegard-Kaplan bands are the new system to which reference was made earlier. These bands correspond to the so-called α-system observed by VEGARD in the luminescence of solid nitrogen and several members of this system appear with considerable intensity in the auroral spectrum.

The similarity between the afterglow spectrum and the auroral spectrum and also between the discharge and afterglow spectra, leads one to the belief that an auroral display is a succession of discharges and afterglows. When one looks for a reason for the similarity between the afterglow and the discharge spectra, one reason immediately presents itself. It is now generally recognized that a metastable state of nitrogen is fundamentally responsible for the afterglow, and hence we assume that the unusual spectroscopic phenomena that take place in the part of the tube in which the afterglow is present, must be traced to the presence of metastable molecules. The discovery of the Vegard-Kaplan system, $A^3\Sigma \rightarrow X^1\Sigma$ confirms the assumption that the metastable molecule in the afterglow is the one in the $A^3\Sigma$ level. If the entire nitrogen-gas in the tube consisted of these metastable molecules then in all probability these peculiarities of the spectrum which can be traced to the metastable molecules would be enhanced and there would be no difference between the spectra of the discharge, afterglow and the aurora. In the laboratory the number of metastable molecules is limited to a great extent by collision with the walls of the tube, and since this limitation

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is not present in the upper atmosphere, one would expect a much larger concentration of metastable molecules there than in the laboratory. In fact one can briefly distinguish between the auroral spectrum and the normal laboratory spectrum of N_2 by saying that, the auroral spectrum is characteristic of metastable nitrogen molecules and that the normal laboratory spectrum is characteristic of normal nitrogen molecules. More will be said about the oxygen part of the auroral spectrum in the report on the light of the night-sky (p. 140).

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PROPAGATION
DES ONDES RADIOÉLECTRIQUES.

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VARIATIONS OF UPPER ATMOSPHERIC IONIZATION

by

L. V. Berkner.

Investigations of the ionosphere, which bring under observation regions of the high atmosphere directly exposed to the radiation of the sun through effectively its whole spectrum, may be expected to yield results bearing directly upon the changes of such radiation. Hence, with the development of suitable technique, systematic series of observations have been commenced at a number of locations—notably by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington at its magnetic observatories near Huancayo, Peru, and near Watheroo, Western Australia, and by the National Bureau of Standards at Washington, D. C.

Results of these observations (see references 1, 2, 3, 4 cited at end of article) show that at night two general regions are apparent, confirming earlier observations (5, 6) in this respect; while in the daytime, with small zenith-angles, three regions are predominant. The lowest, or E-region, is found to have an average virtual-height of approximately 100 km. The second or F-region observed at night is above the E-region with a virtual height of roughly 250 km. With the advent of sunlight, the virtual height of this region is observed to decrease, and, as the zenith-angle becomes small, the region appears to separate into two distinct ionized regions; the lower or F_1-region sinks to a virtual height of about 180 km, while the upper or F_2-region rises to virtual heights of 300 km or higher. With sunset, these two regions appear to merge, again forming the night F-region. This effect is illustrated in fig. 1, drawn for data taken at Huancayo.

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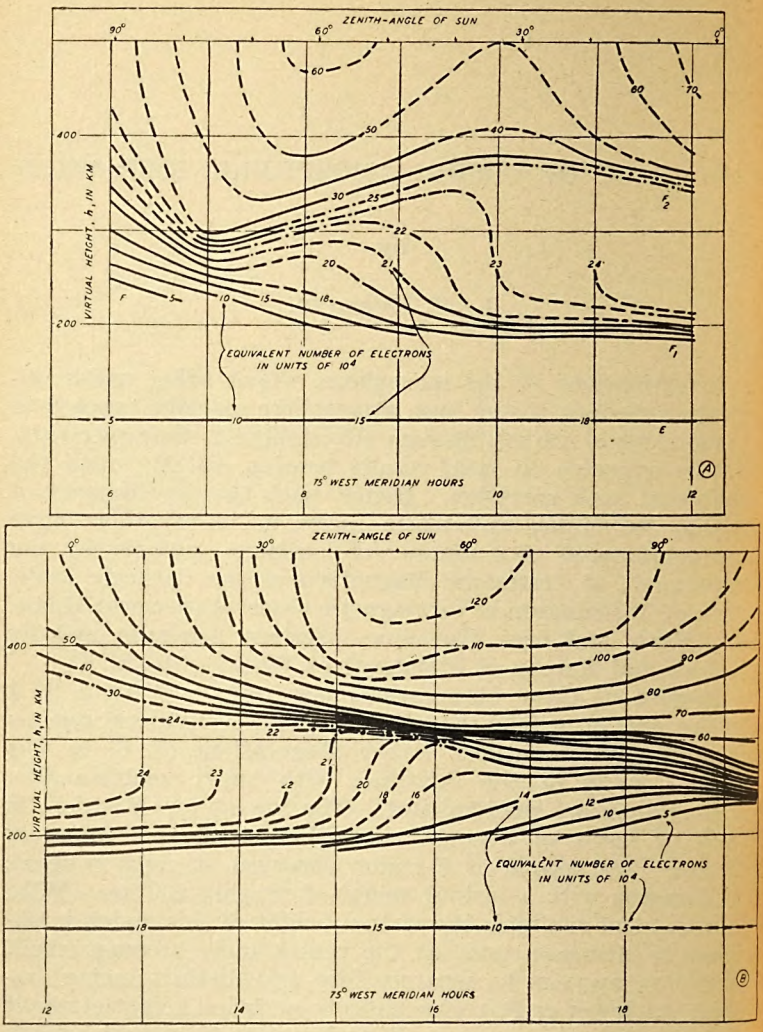

FIG. 1—ISO-IONIC CHART FROM SIMPLIFIED VIRTUAL-HEIGHT VERSUS IONIZATION GRAPHS, HUANCAYO MORNING FEBRUARY 14, 1934 (A); AFTERNOON FEBRUARY 28, 1934 (B)

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Consideration of the changes of ionization with latitude and season has given further information of the distribution of this ionization, particularly in the F-region. It has been shown (2) that a distinct separation of the F_1-and F_2-regions usually occurs with zenith-angles less than about 40°, while

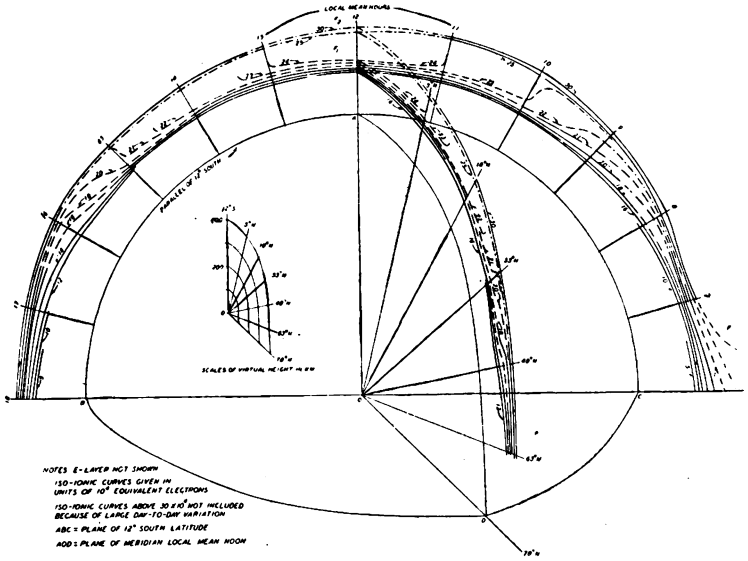
LOCAL MEAN HOURS
PARALLEL OF 12° SOUTH
SCALES OF VIRTUAL HEIGHT IN KM
NOTES E-LAYER NOT SHOWN
150-IONIC CURVES GIVEN IN UNITS OF 10^5 EQUIVALENT ELECTRONS
150-IONIC CURVES ABOVE 30 KM NOT INCLUDED BECAUSE OF LARGE DAY-TO-DAY VARIATION
ABC = PLANE OF 12° SOUTH LATITUDE
ADD = PLANE OF MERIDIAN LOCAL MEAN NOON

FIG 2 – SKETCH SHOWING PROBABLE GEOGRAPHIC DISTRIBUTION F_2-LAYER (DATA 1931–1934) FOR SUN'S DECLINATION 12° SOUTH

in the areas where the zenith-angle is greater than about 40° these two regions are observed to merge into the single F-region. Thus the F_2-region must appear as a sort of « circular bulge » under the sun, with the F_1-region which lies underneath depressed somewhat below the level of the F-region. The sketch of fig. 2 serves to illustrate this distribution. It must not be supposed from this discussion that these conditions are repeated exactly from day to day, for the zenith-angles at which separation is distinct are found to very considerably at a particular station. The separation is also apparently a function of the rate of change of zenith-angle, so

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that the area just described is apparently elongated somewhat in a north-south direction.

The existence of additional regions of ionization has been suggested from time to time by several investigators. A decision concerning such regions may be questionable on the basis of existing evidence. The experimental technique used in such observations makes it difficult to separate effects of two or more regions of nearly the same ionization from effects of inhomogeneity of a single region. Likewise, in the case of very high « layers » reported, a decision must await proof that the reflections observed are coming from above. More information in this direction can be expected from observations during eclipses of the sun and from observations using the continuous automatic multi-frequency technique.

Variations of maximum ionization of these various regions may be classified into four general types, namely, (a) diurnal, (b) annual, (c) sporadic, and (d) long-period. The diurnal variation of maximum ionization for the E-layer, and for the F_1-layer during the period of its separate existence, is usually repeated with fair regularity from day to day, and is apparently mainly a function of the zenith-angle of the sun. During the night, the maximum E-layer ionization decreases on an average. Such a diurnal variation might be expected on the basis of the observations taken during the eclipse of August 31, 1932 (7) from which it was shown that the larger portion of the ionization of the E- and F_1-regions must be attributable to an ionizing agency from the sun traveling at the velocity of light (most probably ultra-violet light). Similarly the annual changes seem to be of a seasonal character such as would be established by the ionization-distribution just described, with the separation of the F_1- and F_2-layers hardly apparent in latitudes where the minimum zenith-angle is large.

The diurnal variation of maximum ionization of the F- and F_2-regions is not so simple and at present offers much room for speculation. The ionization of the F-region decreases generally during the night—with certain interesting exceptions shown by GILLILAND (4). At sunrise, ionization commences quite rapidly when the sun's rays are tangent to the earth's atmosphere at a point about 125-175 km above the earth's surface (8).

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In the latitude of Washington during December, the maximum F-region ionization is usually reached within an hour or two after noon. During June at Washington, and throughout the year at Huancayo, however, the rapid rise in F-region ionization (becoming F_2-region ionization at small zenith-angles) is usually followed by a decrease to a minimum before noon, with a rise to a greater maximum later in the afternoon again followed by a decrease as night conditions set in. These daytime observations of the F- and F_2-regions show two outstanding characteristics, namely, (a) a variability of as much as two to one in maximum ionization from day to day and a general lack of any detailed repetition of form of variation, and (b) a much higher indicated ionization at Washington at noon during December than during June. The highest apparent F_2-region ionization observed at Huancayo has also occurred near the southern solstice. Extended observations are only now becoming available from Watheroo. It is therefore as yet impossible to map out any general surface features of the F_2-region as has been the case with the lower regions. It seems extremely significant, however, that the highest ionized region, existing as it does in a space above which there can be little absorption in the ultra-violet, should be subject to such erratic changes as compared to the lower regions.

In addition to the variations of ionization already discussed, sporadic, sudden ionizations of all regions are frequently observed, occurring most frequently in the E-region. Such sudden increases are observed both during the day and night, and as yet no convincing evidence has been offered as to the origin of such effects. During such periods, the ionization may increase to several times the normal value, the abnormal condition lasting from a few seconds to several hours. There is also occasionally observed additional stratification of a region. This is especially true of the F_2-region which is sometimes observed to separate so that an F_3-layer is formed above it.

The observations of maximum December ionization of the F-region at Washington over a period of years shows a long-period change with the maximum values occurring near the sunspot maximum. Similarly during the period of observation at Huancayo, the variation in the annual maxima is found to be increasing. Such changes are of comparatively

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large magnitude and are immediately suggestive of a direct relation to changes in solar radiation. A conclusion can hardly be reached, however, until observation has extended over a much longer period.

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(1) KIRBY, BERKNER, and STUART, « Proc. Inst. Rad. Eng. », v. 22, 481-521 (1934).

(2) BERKNER and WELLS, « Terr. Mag. », v. 39, 215-230 (1934).

(3) BERKNER and WELLS, « Proc. Inst. Rad. Eng. », v. 22, 1102-1123 (1934)

(4) GILLILAND, « Nature », v. 134, 379 (1934).

(5) APPLETON and GREEN, « Proc. R. Soc. A. », v. 128, 159-178 (1930).

(6) SCHAFER and GOODALL, « Proc. Inst. Rad. Eng. », v. 19, 1434-1445, (1931).

(7) KIRBY, BERKNER, GILLILAND and NORTON, « Proc. Inst. Rad. Eng. », v. 22, 247-264 (1934).

(8) FLEMING, « Terr. Mag. », v. 39, 305-313 (1934).

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ABSORPTION
DANS LA HAUTE ATMOSPHÈRE TERRESTRE.

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ABSORPTION DU RAYONNEMENT ULTRAVIOLET SOLAIRE DE COURTE LONGUEUR D'ONDE PAR L'OXYGÈNE DES COUCHES SUPÉRIEURES DE L' ATMOSPHÈRE

par

D. CHALONGE et E. VASSY.

Les plus courtes longueurs d'onde du rayonnement solaire qui parviennent à la surface de la terre sont voisines de 2950 A. Les radiations de longueur d'onde inférieure sont pratiquement arrêtées de façon complète par l'ozone contenu dans la haute atmosphère terrestre. Mais on peut montrer facilement au laboratoire qu'une couche d'ozone qui absorbe complètement le rayonnement d'une source ultraviolette quelconque, au-dessous de 3000 A, garde une transparence notable pour les radiations voisines de 2100-2200 A. Cependant, diverses tentatives faites jusqu'ici pour déceler le rayonnement solaire vers 2100-2200 A ont échoué (1) : il faut en conclure qu'à l'absorption par l'ozone s'ajoute dans cette région spectrale une absorption supplémentaire.

Au cours de recherches récentes sur la transparence de la basse atmosphère (2) nous avons pu montrer, de façon nette, que cette absorption supplémentaire est due à la molécule

(1) LAMBERT, DÉJARDIN et CHALONGE, « Comptes Rendus », 177 (123), p. 177. Il semble cependant que Schein ait pu récemment trouver ce rayonnement à l'aide d'une cellule spéciale.

(2) CHALONGE et VASSY, « Journal de Physique », 5 (1934), p. 309 et « Revue d'Optique », 13 (1934), p. 113.

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d'oxygène. Sous une grande épaisseur l'oxygène présente au-dessous de 2700 A une absorption constituée par une dizaine de bandes dont la structure fine apparaît très facilement. Elles sont suivies au-dessous de 2420 A par un spectre continu : cette longueur d'onde limite correspond exactement à l'énergie de dissociation de la molécule d'oxygène en deux atomes neutres non excités (1) et le spectre continu correspond à l'absorption suivie de dissociation de la molécule en deux atomes neutres possédant une énergie cinétique variable.

C'est à cette absorption continue par l'oxygène que l'on peut attribuer l'arrêt des radiations de courte longueur d'onde qui ont pu traverser la couche d'ozone.

On voit de plus, que des atomes d'oxygène peuvent être produits, à une profondeur assez grande dans l'atmosphère par les radiations de longueur d'onde inférieure à 2420 A.

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(1) HERZBERG, « Naturwiss. », 20 (1932), p. 577.

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SUR LA PRODUCTION D'OZONE ATMOSPHÉRIQUE PAR LES ÉLECTRONS SOLAIRES PENDANT L'HIVER POLAIRE

par

D. BARBIER, D. CHALONGE et E. VASSY.

L'existence d'un maximum printanier d'ozone d'autant plus important que la latitude du lieu l'observation est plus haute, a fait émettre l'hypothèse que le plus grand maximum devait s'observer à la fin de l'hiver dans les régions polaires et qu'il devait être produit pendant les aurores par les électrons solaires (ou par les électrons secondaires produits par ces électrons solaires). Il était intéressant de vérifier directement ce fait et de mesurer la valeur du maximum d'ozone. C'est ce que sont en train de tenter MM. BARBIER, CHALONGE et VASSY, par l'étude des bandes de l'ozone dans les spectres des étoiles *A* et *B*. Ce travail est exécuté à la Station scientifique Abisko (lat. 68°20'), Suède.

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SPECTROPHOTOMÉTRIE VISUELLE DU SOLEIL ; ÉTUDE VISUELLE DE L' OZONE ATMOSPHÉRIQUE

par

J. GAUZIT.

En cherchant une méthode simple pour le dosage de l'ozone atmosphérique, j'ai été amené à réaliser une partie du programme proposé dans le dernier rapport par M. CH. FABRY (1) pour l'étude du rayonnement solaire.

I. — J'ai construit un spectrophotomètre visuel, à coin absorbant, qui permet la comparaison du spectre solaire avec celui d'une lampe étalon. L'appareil est essentiellement constitué par un spectroscope à déviation constante auquel j'ai ajouté un deuxième collimateur à angle droit du premier et un cube de Lummer, placé entre les collimateurs et le prisme dispersif ; l'oculaire est enlevé et l'on regarde à travers une fente, placée dans le plan focal de l'objectif. L' œil voit ainsi, éclairées en lumière sensiblement monochromatique, les plages du cube photométrique, dont il peut vérifier facilement l'égalité de brillance. L'image du soleil est projetée, par l'intermédiaire d'un héliostat et d'une lentille achromatique, sur la fente du premier collimateur. Le deuxième collimateur reçoit, d'une lampe à filament rectiligne, alimentée sous une différence de potentiel constante de 6 volts par une batterie d'accumulateurs, un flux lumineux réglable au moyen d'un coin absorbant. Pour amener à l'égalité les plages du cube

(1) Troisième Rapport de la Commission, page 48.

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photométrique, éclairées, l'une par la lampe, l'autre par le soleil, il faut évidemment réduire d'abord dans un grand rapport (10^{-4} environ) la brillance du soleil, par interposition d'un écran convenable placé après l'héliostat.

L'intervalle spectral étudié a une largeur de 50 Å environ.

L'erreur relative des pointés photométriques est de 3 ou 4 millièmes.

II. — Les mesures sont réalisées, pour une dizaine de longueurs d'onde, dans les deux ou trois heures suivant le lever du soleil ou précédant son coucher. Elles s'interprétent immédiatement en appliquant la loi de Bouguer :

$$\log I = \log I_0 - m \Delta,$$

qui relie l'intensité I du rayonnement solaire à la masse d'air m qu'il a traversée (en prenant pour unité la masse d'air suivant la verticale au-dessus de l'observateur). L'étalonnage du coin donne log I à une constante près. Pour de belles journées les points des courbes : log I = f (m) s'alignent sur une droite avec une grande précision, du moins pour de faibles valeurs de m, n'atteignant pas 10. Pour m supérieur à 10, quelques mesures, obtenues à l'observatoire du Pic-du-Midi (altitude 2850 mètres), m'ont montré que l'on a encore des droites pour les radiations non absorbées par l'ozone ; je ne trouve pas la courbure indiquée par BAUER et DANJON (1) et par LINK (2). Pour une longueur d'onde absorbée par l'ozone, comme 6100 A, je n'ai pas une ligne droite, car l'épaisseur d'ozone traversée n'est pas proportionnelle à la masse d'air.

III. — Les courbes précédentes donnent par extrapolation les valeurs de log I_0, pour les diverses longueurs d'onde étudiées, avec une erreur absolue qui peut être inférieure à 0,002 ; ces valeurs ne sont évidemment connues qu'à une constante près, qui dépend de l'appareil. Il y aurait intérêt, pour l'étude des variations solaires, à réaliser de telles mesures comparativement avec celles de E. PETTIT, qui détermine le rapport entre l'intensité du rayonnement solaire dans l'ultraviolet et dans le vert.

(1) Premier Rapport de la Commission, page 117.

(2) « Bulletin de l'Observatoire de Lyon », t. XI, n. 10, (1929), page 229.

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Si, comme il est probable, le rayonnement solaire est constant dans la région visible du spectre, l'évaluation expérimentale des différences : $\log I_0 - \log I$ permet une détermination rapide de l'absorption atmosphérique.

IV. — La variation avec la longueur d'onde de la densité optique de l'atmosphère, suivant la verticale, permet de doser l'ozone atmosphérique, par la méthode de CABANNES et DUFAY (1). L'incertitude est inférieure à 10 %.

V. — Les dosages précédents par visée directe du soleil ne sont que rarement réalisables. J'ai réussi à adapter, à l'étude visuelle de l'ozone atmosphérique, la méthode du ciel bleu, imaginée par CABANNES et DUFAY (2) pour l'étude des bandes ultraviolettes de l'ozone. La difficulté consistait à mesurer la faible absorption produite par l'ozone dans la région visible du spectre en éliminant les effets des troubles atmosphériques qui peuvent être supérieurs à l'effet d'absorption cherché.

J'ai résolu le problème de la manière suivante : le spectrophotomètre permet la comparaison du ciel au zénith et de la lampe étalon pour divers intervalles spectraux choisis, soit à l'intérieur, soit à l'extérieur des bandes de l'ozone, en dehors des régions comprenant des raies de Fraunhofer intenses ou des bandes telluriques. Lorsque les plages du spectrophotomètre ont été égalisées par déplacement du coin photométrique, la densité du coin est égale à $\log \frac{i'}{i}$; i' et i désignant les flux lumineux à comparer émis respectivement par la lampe et par le ciel. Il suffit alors de tracer la courbe représentant, « à un instant donné » $\log \frac{i'}{i}$ en fonction de la longueur d'onde: on constate, dans la région d'absorption de l'ozone, une déformation de la courbe, qui donne immédiatement la densité optique de l'ozone atmosphérique, dans la direction des rayons solaires. Deux ou trois mesures très rapides obtenues avec différentes distances zénithales du soleil donnent par extrapolation l'épaisseur de l'ozone suivant la verticale ; en prolongeant les mesures lorsque le soleil est bas sur l'horizon, on peut étudier la répartition verticale de l'ozone.

(1) « Journal de Physique », 6e série, 7 (1926), page 257.
(2) « Journal de Physique », 6e série, 8 (1927), page 125.

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VI. — Par emploi de l'une ou l'autre méthode, et principalement de la seconde, j'ai pu réaliser des dosages à peu près réguliers d'ozone, entre janvier 1933 et mars 1934. Dans une trentaine de cas j'ai pu évaluer l'altitude moyenne de l'ozone atmosphérique ; j' obtiens des nombres compris entre 20 et 50 km. la moyenne étant 33 km. ; mes déterminations indiquent que, en général, l'altitude de l'ozone croît avec son épaisseur.

Quelques observations directes du soleil jusqu'à l'horizon m'ont permis de mettre directement en évidence les inégalités de distribution de l'ozone dans une même couche horizontale.

Par les journées de calme météorologique, ces observations montrent nettement que l' hypothèse de la « couche d'ozone » est insuffisante et elles donnent une valeur approximative de la quantité d'ozone contenue dans la troposphère.

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NEW INVESTIGATIONS ON RADIATION AT THE AROSA LIGHT-CLIMATIC OBSERVATORY

by

F. W. PAUL GÖTZ.

Meteorological measurements of radiation may be described as measurements which allow us to derive the quantity, quality, and vertical distribution of the atmospheric constituents which absorb or emit radiation.

1. *Ozone.* The « reversing (*Umkehr*) effect » of the zenith light has provided the results expected (1) after its discovery, although it was difficult to explain at first (2).

In cooperation with DOBSON and MEETHAM (3) the mean height of the ozone layer above Switzerland is found to be 22 km. The vertical distribution from nearly ground level up to about 40 km. has also been studied, and it is hoped to investigate greater heights by means of the photon counter (4). REGENER's (5) skill as an experimenter has given us a sudden and unexpected confirmation of the above results by recording automatically the ultraviolet solar spectrum at a height of 31 km., the more satisfactory as our indirect methods are based at present on a great quantity of systematic material.

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(1) GÖTZ F. W. P., *Zum Strahlungsklima des Spitzbergensommers,* « Gerl. Beitr. z. Geophys. », 31, 147 (1931).

(2) « Zeitschr. f. Astrophys. », 8 (1934), 267.

(3) GÖTZ, MEETHAM A. R. and DOBSON G. M. B., *The Vertical Distribution of Ozone in the Atmosphere,* « Proc. Royal Soc. », (A) 145, 416, (1934).

(4) GÖTZ, SCHEIN M. und STOLL B., « Helv. Phys. Acta », 7 (1934), 485.

(5) REGENER E. und V., « Phys. Z. », 19 (1934), 788.

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To establish the distribution curve for the first lower layers the measurements already mentioned in the Third Report on the ultraviolet absorption of horizontal layers, including those by LADENBURG, have been continued at different heights in the Alps.

Comparing the values obtained at Arosa (1860 m.) and Chur (600 m.) (1) we find oxygen bands below 2700 A. Investigations on the nature of another absorption have not as yet been concluded (2).

Thanks to a donation by the Geophysical Union it has been possible to continue this research at still greater differences of heights. Measurements have been undertaken simultaneously by my party on the Jungfraujoch (3500 m.) and by an independent party consisting of Drs. CHALONGE, VASSY, and BARBIER at Lauterbrunnen (800 m.), the two parties also interchanged their stations (3).

We may note with satisfaction that E. MEYER, M. SCHEIN, and B. STOLL proved, for the first time, the existence at Arosa of a solar radiation at 2100 A (4).

A contribution on the question of ozone in different latitudes has been supplied by some selected tests during the polar night at Tromsö, they show quite at low amount of ozone(5) during the month of December. Thus the ultraviolet sun-radiation, in the writer's opinion, appears to be the principal source of ozone. Regarding the question of a connection between ozone and solar activity, a long series of daily measurements of the ozone content made at Arosa will be useful. The reductions of these observations have been delayed for want of assistance.

2. *Atmospheric Turbidity.* Cooperation to the « Tabellen der Intensität der Sonnenstrahlung in Nord und Mitteleuropa » was effected mainly in the hope of obtaining a continuous record of atmospheric turbidity. From our last

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(1) GÖTZ und MAIER H.-LEIBNITZ, « Z. f., Geophys. », 9 (1933), 253.

(2) GÖTZ, *Verh. Schweiz Naturf. Ges.* 1934, Zürich.

(3) CHALONGE D., GÖTZ and VASSY E., « Naturwiss. », 22 (1934), 297.

(4) « Nature », 134 (1934), 535.

(5) TÖNSBERG E. und GÖTZ, *Ozon in der Polarnacht*, « Naturwiss. », 23, p. 354 (1935).

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results it may be doubted whether sufficient measures of turbidity could be obtained by the use of non-spectroscopic methods.

During the past ten years the writer has pointed out the anomaly that the ultraviolet radiation of greater wave-lenghts will be weakened to a greater degree in the lower atmospheric layers than that of shorter wave-lengths (1). This has been proved by continuous measurements and also by theory (2).

The dependence on wave-length of the turbidity extinction is not only caused by the magnitude of the particles but also by the material content. This should be of interest for the solution of several problems in atmospheric optics and astrophysics.

3. *Night-sky Light.* Thanks to the Foundation for scientific research at the University of Zürich which has placed at my disposal a quartz spectrograph F/1 new research in this field can now be undertaken.

The writer hopes to continue for a long time a series of measurements of the intensity mainly of line λ 5577. Further, research on the height of the emitting layers (3), and the emission at day time (4).

For the other activities of our small observatory see « Tätigkeit des Lichtklimatischen Observatoriums Arosa, 1934 » (5).

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(1) GÖTZ, *Trübung und anomale Extinktion. Intern. Strahlungskomm.* Frankfurt/M., 1932, 53, Utrecht, 1933.

(2) GÖTZ, *Das Gesetz der Verfärbung bei Diffusion,* « Astr. Nachr. », 255, Nr. 6100 (1935).

(3) GÖTZ, *Methode zur Bestimmung der Schichthöhe des nächtlichen Leuchtens* « Met. Z. », 51, 190, 1934.

(4) « Vierteljahrschr. Astr. Ges. », 70 (1935), p. 343.

(5) « Jahresber. Naturf. Ges. Graubündens », 72, p. 106, Chur, 1934.

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WAVE LENGTH MEASUREMENTS AND ANALYSIS OF THE EMISSION SPECTRUM OF THE UPPER ATMOSPHERE

by

L. A. SOMMER.

It is well known (1) that the upper atmosphere is emitting in all geographical latitudes the line λ 5577. RAYLEIGH and SLIPHER occasionally observe two further lines each (1); the first one at λ 4210 and λ 4435; the latter one at λ 4180 and λ 4450. Furthermore, SLIPHER (2) has been measuring in the long-wave visible spectral range the lines λ 5892, λ 6315, λ 6530, λ 6850 and λ 7270. A classification of these lines has not been given.

The following describes the results of my own measurements, and, as far as possible the classification of the lines, which gives information of the chemical composition and the radiation mechanism of the upper atmosphere (3).

The long-wave length part of the spectrum up to λ 5265 has been photographed in fall 1929 at the Mount Wilson Observatory in Pasadena, Cal.; the short-wave length part, in winter 1928-29 on the Mount Hainberg near Göttingen (Geophysical Institute). Lines of intensity 1 are so faint, that some of them may not be real.

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(1) SOMMER L. A., « Zeitschr. f. Physik », 57 (1929), 587.

(2) SLIPHER V. M., « Publ. Astr. Soc. Pacific », 61 (1929), 263.

(3) SOMMER L. A., « Zeitschr. f. Physik », 51 (1928), 451; 57 (1929), 582; 77 (1932), 374; 80 (1933), 273; 84 (1933), 268.

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TABLE I.

Wave Length Measurements and Analysis of the Spectrum of the Upper Atmosphere.

Spectrum of the Night-Sky					Spectrum of the Polar Aurora			
λ	Int.	Descr.	Classification	Remarks	λ	Int.	λ	Obs.
7280	1	$H_2\,O$	(1, 3, 0) → (0, 0, 0)	7290 (1) ; 7270 (1)				
6940	1	$H_2\,O$	(3, 1, 0) → (0, 0, 0)	6937 (1) ; 6942 (2)				
6860	6	$_2O$	$^1\Sigma \rightarrow {}^3\Sigma$; v′ = 1, v″ = 0	6863 (6) ; 6857 (5)				
6761	1			6752 (1) ; 6770 (1)	6758	2		
6721	1							
6663	1			6673 (1) ; 6654 (1)	$6660/_{50}$	1		
6582	2			6583 (2) ; 6581 (4)	6577	1	6574	G
6528	7	$H_2\,O$	(1, 3, 1) → (0, 0, 0)	6530 (7) ; 6526 (6)	$6513/_{36}$	1		
6508	2							
6454	1			6479 (4)	$6440,_{55}$	1	6451	G
6418	1							
6409	1			6421 (2)	6398	1		
6363	2	O	2 p $^1D_2 \rightarrow$ 2 p $^3P_1$	6361 (2) ; 6365 (1)	6367	2		
		O	2 p $^1D_2 \rightarrow$ 2 p $^3P_2$					
6298	7	O_2	$^1\Sigma \rightarrow {}^3\Sigma$; v′ = 2, v″ = 0	6296 (7) ; 6300 (6)	6302	3	6306	G
		$H_2\,O$	(3, 1, 1) → (0, 0, 0)					
6229	3			6233 (3) ; 6224 (2)				
6207	3			6209 (3) ; 6204 (1)	6185	1		
6115	1			6120 (1) ; 6110 (2)	$6108/_{26}$	1	6122	G
6090	1							
5992	3			5996 (3) ; 5987 (2)				
5935	1			5931 (1) ; 5940 (2)				
5889	9	$H_2\,O$	(1, 4, 0) → (0, 0, 0)	5987 (9) ; 5991 (8)	5891	1	5948	G
5857	1				5867	1		
5815	1	O_2	$^1\Sigma \rightarrow {}^3\Sigma$; v′ = 3, v″ = 0	5818 (1) ; 5813 (1)	5833	1		
5775	1			5780 (1) ; 5771 (2)			5776	G
5716	3			5715 (3) ; 5718 (2)				
5682	1			5687 (1) ; 5677 (2)				
5620	1							
5577	10	O	2 p $^1S_0 \rightarrow$ 2 p $^1D_2$		5577		5577	G
5539	1						5539	G
5508	1			5511 (1) ; 5506 (1)			5510	G
5476	2			5480 (2) ; 5473 (1)			5482	G
5448	2			5446 (2) ; 5451 (2)			5449	G
5360	1	O_2	$^1\Sigma \rightarrow {}^3\Sigma$; v′ = 4, v″ = 0	5356 (1) ; 5363 (2)			$5377/_{53}$	G
5314	1			5312 (1) ; 5316 (1)			5300	G
5265	1			5266 (1) ; 5264 (1)	5241	3	5264	G

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TABLE I (*Continued*).

Spectrum of the Night-Sky					Spectrum of the Polar Aurora			
λ	Int.	Descr.	Classification	Remarks	λ	Int.	λ	Obs.
5130	3						5127	G
4860	3						4866	G
4709	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 0, v″ = 2				4707	G
4650	1	N_2 +	$^1\Sigma \rightarrow {}^2\Sigma$; v′ = 1, v″ = 3				4642	G
4552	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 3, v″ = 5				4550	W
4457	1						4446	G
4422	1						4424	W
4278	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 0, v″ = 1				4276	W
4270	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 1, v″ = 5				4257	G
4238	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 1, v″ = 2				4242	W
4209	1							
4200	1	N_2 N_2 +	$^3\Pi \rightarrow {}^3\Pi$; v′ = 2, v″ = 6 $^2\Sigma \rightarrow {}^2\Sigma$; v′ = 2, v″ = 3				4200	V
4186	1						4182	V
4166	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 3, v″ = 4				4166	R
4057	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 0, v″ = 3				4057	S
3999	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 1, v″ = 4				3996	W
3976	1						3986	W
3946	1						8947	W
3943	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 2, v″ = 5				3941	V
3916	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$, v′ = 0, v″ = 0				3918	K
3893	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 3, v″ = 6				3892	K
3883	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 1, v″ = 1				3880	W
3855	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 1, v″ = 2				3861	W
3806	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 0, v″ = 2				3804	W
3791	1						3793	W
3755	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 1, v″ = 3				3755	V
3738	1						3730	P
3722	1							
3710	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 2, v″ = 4				3711	V
3671	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 3, v″ = 5					
3658	1							
3642	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 4, v″ = 6					
3630	1							
3621	1							
3613	1							
3608	1						3607	W
3599	1							
3592	1						3589	W
3582	1	N_2 +	$^2\Sigma \rightarrow {}^2\Sigma$; v′ = 1, v″ = 0					
3578	1	N_2	$^3\Pi \rightarrow {}^3\Pi$; v′ = 0, v″ = 1				3577	V

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Analysis of the Spectrum.

1. *Quadrupol lines of the OI Spectrum.*

λ 5577, the strongest line of the spectrum is identical with the well known green oxygen auroral line, which has been classified as $2p^1S_0 \rightarrow 2p^1D_2$.

λ 6298 and λ 6363 are further transitions between the low-lying metastable levels of the *OI* spectrum (1), namely $\lambda\,6298 = 2p^1D_2 \rightarrow 2p^3P_2$ and $\lambda\,6363 = 2p^1D_2 \rightarrow 2p^3P_1$. Further oxygen atomic lines have not been observed.

2. *The atmospheric oxygen bands (O_2) in emission.*

The well known absorption bands of oxygen have been observed for the first time in the upper atmosphere in emission, and classified as quadrupol radiation between the low-lying, inter-combining, metastable molecular levels $^1\Sigma \rightarrow {}^3\Sigma$ in a similar way as the transitions between the corresponding atomic levels $2p^3P_{210}$, $2p^1D_2$ and $2p^1S_0$ of the oxygen spectrum, and correspond to the special transition of $^1S_0$ — $^3P_{210}$ at 2972 ; especially is : $\lambda\,6860 = {}^1\Sigma \rightarrow {}^3\Sigma$, $v'=1$, $v''=0$; $6298 = {}^1\Sigma \rightarrow {}^3\Sigma$, $v'=2$, $v''=0$; $5815 = {}^1\Sigma \rightarrow {}^3\Sigma$, $v'=3$, $v''=0$; $5360 = {}^1\Sigma \rightarrow {}^3\Sigma$, $v'=4$, $v''=0$.

This classification is justified by the following arguments :

1) the agreement of the wave lengths between the observed bands in emission and the atmospheric oxygen bands in absorption ;

2) the very low absorption coefficients of the atmospheric oxygen bands (O_2) and quadrupol radiation of *OI* ;

3) the difficulty of excitation of these radiations of *OI* and O_2 in emission ;

4) the low excitation potentials ; for $^1S_0$ of *OI* 4,17 volt, for $^1\Sigma$ of O_2 1,62 volt.

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(1) Sommer L. A., « Naturwissenschaften », 18 (1930), 752.

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3. *The atmospheric water vapor bands (H_2O) in emission.*

The well known absorption bands of the water molecule (rotation-oscillation bands of H_2O) have been observed for the first time in the spectrum of the upper atmosphere in emission. They correspond, according to Mecke (1) to the following transitions: λ 7280 (1) = (1,3,0) → (0,0,0); λ 6940(1) = (3,1,0) → (0,0,0); λ 6528 (7) = (1,3,1) → (0,0,0); λ 6298(7) = (3,1,1) → (0,0,0); λ 5889(9) = (1,4,0) → (0,0,0). The maximum excitation energy of these bands requires the band at λ 5889 with only 2,09 volt. The radiations of O,O_2 and H_2O at λ 6298 overlap each other. Therefore, the wave length and intensity measurements are merely approximate.

4. *The second positive nitrogen group (N_2).*

In the short wave length part of the visible spectrum very faint band heads of the second positive nitrogen group corresponding to transitions $^3\Pi \rightarrow {}^3\Pi$ of N_2, with approximately 13 volts excitation energy, have been observed. They are shown in table I (p. 120).

5. *The first negative nitrogen group (N_2^+).*

In the short wave length part of the visible spectrum band heads of the first negative nitrogen group have been observed with extremely low intensity, which are very intensiv in the auroral spectrum, corresponding to transitions of $^2\Sigma \rightarrow {}^2\Sigma$ of N_2^+ and requiring the excitation energy of 19,6 volts. They also are shown in table I.

In consequence of the observation of the nitrogen bands in the short wave length part of the visible spectrum, I have concluded that in the long wave length part, the first positive nitrogen group should also be present (2), which has been classified as transition $^3\Pi \rightarrow {}^3\Sigma$ of N_2, requiring about 9,4 volts

(1) MECKE R., « Zeitschr. f. Physik », 81 (1933), 313, 445.
(2) SOMMER L. A., « Zeitschr. f. Physik », 57 (1929), 600; 77 (1932), 375.

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excitation energy. Actually I found in the spectrum of the upper atmosphere (table I) a number of very faint lines of a similar character as the nitrogen bands in the short wave length part. However, the agreement of wave lengths between the first positive nitrogen group and own observations was not sufficient to justify this identification.

6. *Chemical Composition of the upper atmosphere.*

The analysis of the spectrum shows that the upper atmosphere, where the radiation originates, is mainly composed of O-atoms, O_2—, H_2O—, N_2— and N_2^+—molecules.

Transitions between the low-lying (metastable) levels are giving raise to the most intensive radiation of O, O_2 and H_2O while the nitrogen bands are very faint.

7. *Night sky illumination and auroral light.*

Table I shows the auroral spectrum in comparison to the spectrum of the night sky. The agreement of the wave lengths is very close, while the intensities differ considerably. The analysis of the night sky spectrum therefore includes the classification of the auroral spectrum. From the agreement of wave length structure of the two spectra I have concluded that the night sky illumination and auroral displays should have the same physical origin (1).

8. *Origin of the night sky light.*

The bands of N_2 and N_2^+ are being produced by ultra-violet sunlight; the O_2 and H_2O bands as well as the forbidden O-lines by secondary electrons, which are also produced by ultra-violet sunlight in the upper atmosphere, or as a result of dissociation processes of O_2 and O_3, where by an exchange of energy is taking place between O, O_2 and H_2O by collisions of the second kind.

(1) SOMMER L. A., « Zeitschr. f. Physik », 57 (1929), 594.

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COSMIC ULTRA-RADIATION AND THE FLOCCULI OF THE SUN (*)

by

AXEL CORLIN.

As a part of an international cooperation, a so called Steinke-apparatus recorded the ionisation caused by cosmic ultra-radiation at Abisko in northern Sweden (geogr. lat. $+68°21'$; geom. lat. $+66°5'$) from 23rd Sept. 1932 until 7th July 1933. The ionisation chamber of the apparatus was surrounded by a lead shield 10 cm. thick, and this shield was sometimes upwards open with an aperture of $\pm 45°$ east-west and $\pm 60°$ north-south as counted from the middle of the chamber, sometimes the shield was closed also upwards. With few interruptions the apparatus recorded the ionisation during every hour day and night.

For days with a sufficient number of hourly records (not less than 19) the daily mean values of the ionisation have been formed, and these mean values have been compared both with the sunspot numbers and the flocculi figures of the same days as published by the Observatory of Zürich under the auspicies of the International Astronomical Union. As to the flocculi figures the sum of the mean flocculi figures for calcium flocculi and bright and dark hydrogen flocculi for every day has been taken. The material has been divided according to open and closed shield.

(*) Abstract from a paper entitled: *Cosmic ultra-radiation in northern Sweden*, « Annals of the Observatory of Lund », n. 4.

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For closed shield some correlation is found between daily means of ionisation and sunspot numbers, but a far more pronounced correlation is found between the same daily means of ionisation and the above-mentioned sums of flocculi-figures. The coefficient of correlation for the whole material for closed shield (104 days) is $+0.52 \pm 0.07$. When days with an air-pressure less than the mean air-pressure at Abisko (720 mm. Hg) are excluded, the remaining days (49 in number) having calm weather show a coefficient of correlation as high as $+0.81 \pm 0.05$, so that meteorological disturbances seem to disturb the correlation between ionisation in a closed vessel near sea level and the flocculi frequency on the sun. Remembering that cosmic ultra-radiation as recorded at the bottom of the atmosphere is subject to disturbances of various kinds and that the flocculi figures are estimates and no exact measure of the flocculi frequency, we may hardly expect a better agreement between the two phenomena as studied in this way.

The increase of the ionisation for every unit of mean flocculi-figure is 0.010 pairs of ions per cm. and sec. in air of normal pressure, that is 0.36 % of the total ionisation due to that part of cosmic ultra-radiation which is capable of penetrating the whole atmosphere and in addition 10 cm. of lead. This percentage indicates that the sun at maximum frequency of flocculi (that is a figure of 5 for each kind of flocculi or a sum of 15) contributes 5.4 % of the total ionisation of cosmic ultra-radiation within 10 cm. of lead in excess of the possible but unknown contribution, when no flocculi are visible on the disc of the sun.

The records for open shield also show a correlation with the flocculi frequency but more complicated. The daily means of ionisation from March and May 1933 (no records being made during April), when the intensity of cosmic ultra-radiation as recorded near sea level was very low, show a correlation with the flocculi frequency at least as high as did the records with closed shield. For the rest of the time the daily means of ionisation are very scattered but show in spite of this fact also a correlation with the flocculi frequency although less pronounced.

Also the records with a closed iron shield 12 cm. thick performed by E. STEINKE at Königsberg in 1929 have been

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investigated in a similar manner and show a similar complicated correlation with the flocculi frequency. If Steinke's material is divided into two parts according to comparatively low (March-May 1929) and comparatively high (June-November 1929) intensity of cosmic ultra-radiation, both parts show an increase of the ionisation for increasing flocculi frequency, whereas the total material has a more circular distribution in the ionisation-flocculi diagram. There is thus an indication of a correlation between the ionisation in a closed vessel near sea level and the flocculi frequency both from Abisko and Königsberg, but also an indication that this correlation is disturbed by other factors, which play an important *rôle* in the yearly variation of cosmic ultra-radiation as recorded at the bottom of the atmosphere.

The necessary precaution about such an important conclusion as to an ultra-penetrating radiation from our sun capable of penetrating the whole atmosphere and in addition 10 cm. of lead (11 meters of water-equivalent) and variable with the flocculi frequency in the author's opinion forces us first to ask for some further confirmation of the mentioned results before we may be certain that such a radiation exists. But it may be allowed to speak about a very strong indication of such a radiation from the Abisko results. An important and probably wholly deciding test of the indicated relation is to be expected from an investigation of the simultaneous records of similar Steinke-apparatus at Abisko, Königsberg, Innsbruck, and Amsterdam in 1931-34 as collected at Steinke's Institut in Königsberg. The author has been informed about some results of this international cooperation, and so far the above mentioned relation is wholly confirmed.

A general confirmation of the above mentioned relation will open an important field of research both for the investigators of cosmic ultra-radiation and for the astronomers. It is also likely that, as a consequence, some light will be thrown upon the origin of cosmic ultra-radiation. It may be allowed here to point out a now highly desirable subject for solar research.

As to the origin of cosmic ultra-radiation two essentially different kinds have been considered, namely atomic transformations capable of producing such highly penetrating rays and violent accelerations in strong or extended fields of force.

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Historically it is well understood that the first-mentioned kind of origin has been mostly considered, as cosmic ultra-radiation was earlier generally assumed to be an ultragamma-radiation. Recent results indicate, however, more and more that cosmic ultra-radiation is a corpuscular radiation even as to its hardest constituents, and therefore we may pay attention to the second and less noticed kind of origin. In fact, we know nothing at all about atomic transformations capable of producing so highly penetrating corpuscular rays, but we know that strong induction fields are present on the sun, namely in the increasing or decreasing magnetic fields of the sunspots. According to the comprehensive memoir about the solar phenomena by G. ABETTI in *Handbuch der Astrophysik*, Bd. IV, there are also indications of extended vortices in the structure of the flocculi, which in the case of a confirmation of the relation between ionisation near sea level and the flocculi frequency deserve much attention. Corpuscles of electronic mass and capable of penetrating 11 meters of water must have an energy of at least 7.10^9 electron-volts, and W. F. G. SWANN (*Phys. Rev. 43*, 217, 1933) has shown that vortices with a diameter 50 times that of the earth and increasing 2000 gausses in 12 days are capable of accelerating electrons up to an energy of 10^{10} e.-v. Swann considers only sunspots and thinks therefore that our sun is not capable of producing such high-speed corpuscles. But from the above-mentioned memoir by Abetti we find that the vortices indicated by the flocculi on our sun are possibly capable of producing such high-speed corpuscles, depending upon the unknown magnitude of their field strengths. First, the flocculi increase in much shorter time than 12 days, and, secondly, their vortices seem to be much more extended than those of the sunspots. The following lines quoted from ABETTI (*loc. cit.*, p. 121) are suggestive :

« On the hypothesis that the phenomena of the flocculi are of the same nature as those of the aurorae, it is reasonable to suppose that large spots with intense magnetic fields should be more capable of producing alterations in the structure of the hydrogen flocculi lying at a greater distance than small spots with weaker fields. Yet we find, in practice, that some small groups of spots are surrounded by hydrogen flocculi which show an extensive cyclonic structure and which extend

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over distances equal to one third of the solar diameter, while large spots with powerful magnetic fields frequently only affect the flocculi over a much smaller area. These phenomena make it difficult to accept the electromagnetic theory, especially as we know of cases of large spotless regions covered with flocculi of spiral structure whose spectroheliograms in Hα suggest the shape of the lines of force in a magnetic field ».

So far the author knows, the Zeeman effect of flocculi outside sunspot regions or of those « large spotless regions » as mentioned above has not as yet been investigated. With respect to the indicated ultra-penetrating radiation from the sun, variable with the flocculi frequency, and the possible origin of this radiation in rapidly increasing or decreasing magnetic fields associated with the flocculi, it is now highly desirable that the strengths of those fields are investigated at observatories equipped with powerful instruments for solar research.

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LUMIÈRE DU CIEL NOCTURNE.

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ANALYSE SPECTRALE ET POLARISATION DE LA LUMIÈRE DU CIEL NOCTURNE

par

J. DUFAY et J. CABANNES.

Nous avons entrepris, depuis 1933, avec la collaboration de MM. GARRIGUE et GAUZIT, une nouvelle série de recherches sur la composition spectrale de la lumière du ciel nocturne. Les premiers résultats de ces recherches ont été publiés dans les notes et articles suivants :

1) Spectre d'émission du ciel nocturne dans la région ultraviolette, par J. DUFAY (C. R., *198*, 1934, p. 107).

2) Analyse spectrale de la lumière du ciel nocturne au Pic du Midi, par J. CABANNES et J. DUFAY (C. R., *198*, 1934, p. 306).

3) Nouveaux résultats sur la raie verte de l'aurore non polaire dans le ciel nocturne, par H. GARRIGUE (C. R., *198*, 1934, p. 1398).

4) Les radiations du ciel nocturne dans l'intervalle spectral 5000-8000 A, par J. CABANNES (C. R., *198*, 1934, p. 2132).

5) L'extrémité ultraviolette du spectre du ciel nocturne, par J. GAUZIT (C. R., *199*, 1934, p. 29).

6) Considérations théoriques sur la luminescence des hautes couches de l'atmosphère, par J. CABANNES (C. R., *199*, 1934, p. 909).

7) Observation du spectre d'émission du ciel nocturne dans l'ultraviolet, par J. DUFAY (« Journal de Physique », *5*, 1934, p. 523).

8) L'extrémité ultraviolette du spectre du ciel nocturne, par J. GAUZIT (« Journal de Physique », *5*, 1934, p. 527).

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9) Sur l'origine des raies émises par le ciel nocturne dans l'intervalle spectral 5000-8000 A, par J. CABANNES (« Journal de Physique », *5*, 1934, p. 601).

Nous ne donnerons ici que les conclusions essentielles de ces différents travaux en priant le lecteur de vouloir bien s'y reporter pour connaître le détail des observations.

1) L'intervalle spectral étudié s'étend de 3000 à 8000 A environ. Le nombre des radiations mesurées, soit directement sur les clichés avec un microscope, soit après enrégistrement au microphotomètre, est assez élevé : une centaine dans l'ultraviolet ($\lambda < 4000$ A), quatre-vingt environ dans le violet et le bleu ($4000 < \lambda < 5000$ A), soixante-dix environ dans le vert, le jaune, le rouge et l'infrarouge ($\lambda > 5000$ A) ; mais les impressions photographiques sont souvent faibles et les spectres, peu dispersés ; sans doute nos listes de raies sont-elles encore sujettes à révision.

2) Dans le violet et le bleu l'attribution des radiations du ciel nocturne est difficile ; on n'y trouve que très affaiblies les bandes du système négatif et du second système positif de l'azote qui caractérisent, dans ce domaine spectral, les aurores boréales. L'origine des deux groupes de radiations les plus intenses, en 4173 et en 4417-4429 A, reste encore douteuse. Mais nous avons pu identifier dans le ciel nocturne les radiations les plus caractéristiques du spectre d'origine inconnue des noyaux cométaires, et c'est sans doute un de nos résultats les plus importants.

3) Du vert à l'infrarouge nous avons observé, outre la raie verte des aurores 5577 A, qui est la plus intense des radiations émises par le ciel nocturne, certaines bandes du premier système positif de l'azote, les bandes de vibration de la vapeur d'eau et les bandes dites telluriques de l'oxygène. La présence des bandes de H^2O et de O^2 avait d'ailleurs été déjà signalée par SOMMER, et nous nous ne faisons sur ce point, que confirmer ses conclusions.

4) Nous avons comparé le rapport entre l'intensité à l'horizon et l'intensité au zénith des principales radiations violettes et bleues émises par le ciel et les rapports trouvés, variables d'une radiation à l'autre et d'une nuit à l'autre, sont voisins de 1,5. Les bandes et les raies sont donc bien émises dans l'atmosphère supérieure. L'absorption atmosphérique intervenant d'une manière complexe, il est difficile de

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préciser l'altitude des couches lumineuses. En cherchant à tenir compte de l'absorption, nous trouvons des valeurs nettement supérieures à 100 km.

5) Pendant l'année 1933, M. GARRIGUE a photographié la raie verte au Pic du Midi, en toute saison et par tous les temps, au zénith et à l'horizon. Le rapport entre l'intensité de la raie verte à l'horizon et son intensité au zénith reste voisin de 2,0. Ce n'est que très exceptionnellement que la raie verte peut devenir beaucoup plus intense à l'horizon nord. Pour pouvoir déduire de ce résultat l'altitude de la couche émettrice, il faudrait supposer la répartition de celle-ci uniforme, ce qui n'est pas tout à fait légitime, puisque l'intensité de la raie à l'horizon sud n'est pas exactement la même qu'à l'horizon nord. Cependant elle n'en diffère que de deux dixièmes. Si l'on compare le résultat que nous avons obtenu pour les raies bleues à celui qu'obtient GARRIGUE pour la raie verte, il semble que la couche émettrice de la raie verte est à plus basse altitude que celle des raies bleues. Mais l'absorption atmosphérique intervient d'une manière trop complexe pour qu'on puisse arriver actuellement à une conclusion certaine. M. GARRIGUE a aussi étudié la variation d'intensité de la raie verte au cours d'une nuit. A l'horizon nord et à l'horizon sud on retrouve le maximum d'intensité (vers 1 heure) déjà mis en évidence pour la région zénithale par MCLENNAN. Les variations d'intensité au nord et au sud sont parallèles, l'intensité au sud étant toujours supérieure à l'intensité au nord.

6) De nombreuses mesures d'intensité faites chaque mois au moment de la nouvelle lune, de décembre 1933 à janvier 1935, nous ont permis d'établir la variation annuelle de l'intensité des radiations 4173 et 4417. Les meilleures mesures ont été faites sur le groupe 4417-4429. En voici les résultats encore inédits :

MOIS.....	J	F	M	A	M	J	J	A	S	O	N	D
INTENSITÉ...	40	57	133	100	69	91	127	148	112	51	»	48

Le graphique (fig. 1) montre les écarts en plus ou en moins de part et d'autre de la moyenne 89. Nous avons reproduit aussi sur ce graphique la fréquence des aurores boréales, telle qu'elle résulte d'une statistique de 25 ans faite à New-York, une des régions du globe où les aurores boréales descendent à la plus

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basse latitude géographique. La concordance de la variation de fréquence des aurores et de la variation d'intensité des raies bleues du ciel nocturne est impressionnante et ne laisse aucun doute sur l'origine commune des deux phénomènes. Il y a deux minima, lorsque la terre traverse la plan de l'équa-

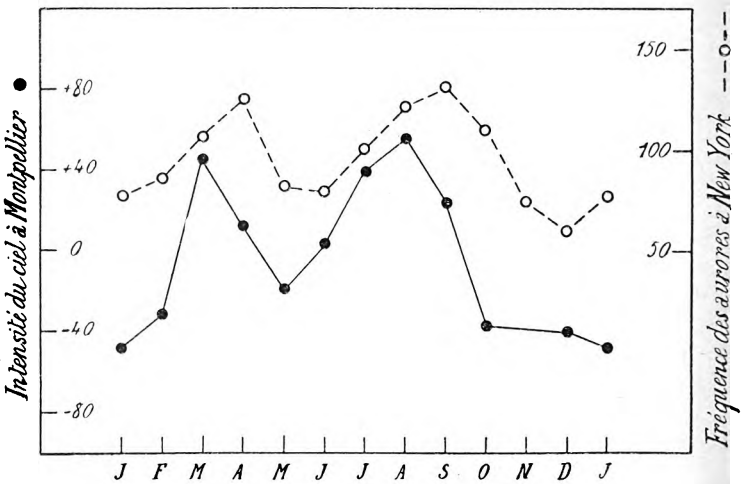

Fig. 1.

teur solaire, et deux maxima en mars et en été, ce dernier étant de beaucoup le plus important.

7) L'étude de la partie la moins réfrangible du spectre a conduit l'un de nous à voir dans la lumière du ciel un phénomène de phosphorescence lié à la présence dans les hautes couches de l'atmosphère de molécules métastables d'azote à l'état A et de molécules d'ozone. On a montré comment les électrons solaires intervenaient dans la formation des molécules N^2 (A) et O^3, et on a analysé le phénomène de phosphorescence ultérieur, dû à des chocs entre les molécules N^2 (A) et O^3, au rayonnement spontané des particules métastables O^2 $(^1\Sigma)$ et O $(^1S_0)$, et enfin à des chocs entre les atomes d'oxygène excités et les molécules H^2O et N^2 (A).

8) Enfin des observations (encore inédites) ont été faites en 1934 sur la polarisation de la lumière du ciel nocturne.

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Elles ont confirmé les résultats obtenus par l'un de nous il y a une dizaine d'années : la lumière du ciel nocturne montre, au moins entre l'horizon nord et le zénith, une faible polarisation et le plan de polarisation passe à chaque instant par le Soleil. La polarisation est plus marquée sur la lumière zodiacale. Une partie de la lumière du ciel nocturne semble ainsi résulter d'une diffusion de la lumière solaire par des molécules gazeuses ou des électrons libres.

NOTE AJOUTÉE SUR ÉPREUVES.

Depuis la rédaction de ce compte-rendu, nous avons obtenu de nouveaux résultats, dont voici l'essentiel :

1) Nous avons confirmé la présence, dans le spectre du ciel nocturne, des bandes de Vegard-Kaplan (système A→X de l'azote), que KAPLAN avait indiquée comme probable (C. R., *200*, 1935, p. 1504).

2) Nous avons été amenés ainsi à modifier notre théorie de la luminescence de la haute atmosphère : la molécule d'ozone n'intervient pas, mais seulement les molécules N^2, O^2 et l'atome O (J. CABANNES, « Helvetica Physica Acta », *8*, 1935, pp. 405-420).

3) Nous avons montré que la raie 5577 et les bandes de Vegard-Kaplan 4435 et 4837 n'étaient pas plus intenses sur la lumière zodiacale que sur le ciel nocturne à la même hauteur. Les autres bandes et raies brillantes observées dans le spectre de la lumière zodiacale sont probablement aussi d'origine atmosphérique (C. R., 201, 1935, p. 696).

4) Le spectre continu, qui fournit, dans l'intervalle 3800-5000 A, les 2/3 environ de la brillance du ciel, peut être attribué pour 1/3 au rayonnement direct des étoiles faibles. Le reste peut provenir de la diffusion de la lumière du soleil et des étoiles par des particules répandues dans tout l'espace au voisinage du plan galactique (J. DUFAY, C. R., 201, 1935, p. 1323 ; WANG SHIH KY, C. R., 201, 1935, p. 1325).

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LIGHT OF THE NIGHT-SKY

by

J. KAPLAN.

An authentic laboratory model of the upper atmosphere may be useful for purposes other than the explanation of the origin of the auroral radiations or the light of the night-sky. It may be possible that by a comparison between spectra of the aurora or the night-sky and those taken in the laboratory we will be able to determine the constitution of the upper atmosphere. The excitation of the green aurora line for example may be used to determine the ratio of oxygen to nitrogen. Recent experiments have shown that the green line is excited with varying intensities as this ratio is changed. As the amount of oxygen increases, the green line goes through a maximum intensity and then gradually disappears when too much oxygen is present. Certainly an upper limit for the oxygen concentration in the upper atmosphere can be determined in this way and eventually perhaps even more accurate determination can be made.

The above mentioned model may be used in other studies such as the absorption of the sun's rays by the various metastable molecules and atoms which are present in the atmosphere. It may not be too speculative to suggest here experiments on the effect of cosmic-rays on a cloud of metastable nitrogen molecules. Other experiments of interest in problems of radio transmission may also be studied in connection with this model.

A remarkable and as yet incompletely understood difference between the new form of active nitrogen and the Lewis-Rayleigh type arises in the excitation of oxygen by these two

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forms of active nitrogen. In studying the excitation of the green line by the older modification of active nitrogen the writer observed in 1928 (1) that when the concentration of oxygen was very small this line appeared in the afterglow and further more that it was the only oxygen line to appear in the spectrum. Since this was the first experiment in which the lone appearance of the green line had been accomplished it was felt that it was at least an important guide to a real understanding of the aurora spectrum. In addition to the green line however there were present in the afterglow the β bands of nitric oxide and since no nitric oxide bands have ever been observed in either aurora or night-sky spectra it was apparent that the excitation of the green line in this afterglow was not the same as its excitation in nature. Recent experiments (2) in the tube, in which the new afterglow appears, have resulted in spectra in which the green line is not only the only oxygen line on the plate but the nitric oxide bands are completely missing. It must be mentioned that these experiments are only in an early stage and no quantitative estimate of the oxygen concentration has been made. Furthermore, there is a very convincing indication that the two auroral red lines λ 6363 and λ 6300 which correspond to the transitions $^1D_2 \rightarrow {}^3P_{2,1}$ are also present. The most significant difference in these two excitations of the green line is the non-appearance of the nitric oxide bands in the later of the two experiments.

The electronic energy of the $A^3\Sigma$ level of N_2 is 49766 $\overline{cms}'$ and that of the $B^3\Sigma$ level of O_2 is 49407 $\overline{cms}'$. Collisions between metastable nitrogen molecules in the lowest vibrational state and normal oxygen molecules also in the lowest vibrational state should result in excited oxygen molecules in the B level. The subsequent transitions to the normal state will yield the Schumann-Runge bands of oxygen. The comparison of the members of this system, both calculated and observed, with the ultraviolet and violet radiations in the light of the night-sky observed by GAUZIT, (3) shows a very

(1) KAPLAN, « Phys. Rev. », 33, 154 (1929).
(2) KAPLAN, « Nature », 135, 229 (1935).
(3) GAUZIT, « Journal de Physique », Series VII, 5, 527 (1934).

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consistent agreement. No laboratory observations of the excitation of the Schumann-Runge bands by collisions with metastable nitrogen have been made but such experiments are planned for the near future.

In all probability the atmospheric bands of oxygen, the well known $A^1\Sigma \rightarrow X^3\Sigma$ transition, are also produced in the night-sky by collisions between oxygen and metastable nitrogen molecules. Their presence in the light of the night-sky has been suggested by several investigators but these bands have never been observed in emission in the laboratory due to the extreme metastability of the $A^1\Sigma$ level. It may be possible however that the writer will be able to observe them in the same tube in which the green aurora line has been observed and a thorough search is being made for these bands.

The *rôle* played by metastable nitrogen molecules in the emission of the aurora spectrum suggested immediately that they probably play an important part in the emission of the night-sky spectrum also. It was thought that the difference between these two spectra could be best expressed by saying that the aurora spectrum is the result of a fairly intense excitation of a gas of these metastable molecules and that the light of the night-sky was due to feeble excitation processes in gas of metastable molecules. The first of these processes has already been discussed in the report on the auroral spectrum (pag. 92). In order to study the second of these processes in the laboratory it was first necessary to produce a large number of metastable molecules and then to study the light emission resulting from a very weak electrical discharge through it. This was first done by passing a rapidly interrupted discharge from a 25000 volt 1K.W. transformer through pure nitrogen. The tube consisted essentially of a one liter bulb to which the electrodes were attached by means of tubing the diameter of which was about 1 cm. The tube was one in which a strong afterglow, such as the one described in the summary of the aurora spectrum, was present. The frequency of interruption was so high as to prevent the current in the bulb from reaching its full value. Under these conditions the Vegard-Kaplan bands underwent a very interesting change in intensity. The members of this system which fall in the near ultraviolet increased in intensity and the negative bands diminished greatly in intensity in comparison with their intensities in a fully deve-

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loped discharge. Since in all probability many metastable molecules are produced in the strong part of the discharge and shot into the bulb the experiment reproduced partly, at least, the conditions presented in the hypothesis given above, namely, a feeble excitation in a cloud of metastable N_2 molecules. On the basis of this result the visible and near ultraviolet members of the Vegard-Kaplan system were calculated and very satisfactory agreement was obtained with GAUZIT'S list of violet and ultraviolet radiations in the night-sky.

In order to confirm that the conditions in the rapidly interrupted discharge resembled closely those in the night-sky a small amount of oxygen was introduced and spectra were obtained on special green sensitive plates. The green aurora line λ 5577 was present and on the plates which have been obtained there was hardly a trace of the first-positive N_2 bands which are normally the most intense radiations in the green, yellow and red parts of the spectrum. In fact, with the exception of the second-positive bands in the blue and violet, which are somewhat stronger than they appear on plates obtained from the night-sky, the present experiments yield plates which are remarkably like those obtained directly from the night-sky.

Most of the radiations from the night-sky can be accounted for by assuming that they belong to known band systems of oxygen and nitrogen. Three intense lines or bands λ 3471, λ 3556 and λ 5893 are among the most important of the unidentified radiations. The line 3471 agrees almost perfectly with the nitrogen atomic line which originates in the low metastable level ^2P and corresponds to a transition to the normal ^4S state of the above. This line has not been observed in the laboratory but the presence of metastable nitrogen atoms where there are metastable nitrogen molecules is not difficult to understand when one recalls the CARIO and KAPLAN theory of active nitrogen in which these and the ^2D metastable atoms play such an important *rôle*.

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VARIATIONS MÉTÉOROLOGIQUES ET CLIMATOLOGIQUES SUR LA TERRE.

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THE RELATIONS OF SOLAR AND METEOROLOGICAL PHENOMENA: A SUMMARY OF THE RESULTS FROM 1925 TO 1934 INCLUSIVE

by

C. E. P. Brooks.

The First Report of the Commission appointed to further the study of solar and terrestrial relationships contained on pp. 66-100 a summary of the literature from 1914 to 1924. This summary is continued here in a more generalised form, only the main results being briefly referred to.

The majority of the investigations described still use the relative sunspot number as an index of solar activity, but it is becoming evident that the relation between the sunspot numbers and solar radiation is complex. Thus F. Baur (1,2) found a small negative correlation, the highest values of solar radiation apparently occurring chiefly between the maxima and minima of sunspots. He suggests that the relationship varies from direct to inverse in different spectral regions and that the effect on terrestrial temperatures is largely indirect, *e. g.* due to a variation in transparency. In conformity with this, severe winters in Berlin have a marked tendency to occur near sunspot maxima or minima. Several other investigations have shown a similar type of variation. Thus S. W. Visser (3)

(1) Baur F., *Zur Frage der Realität der Schwankungen der Solarkonstante*, « Met. Zs. », 49, 1932, pp. 15-18, Braunschweig.

(2) Baur F., *Changes in the solar constant of radiation*, « Mon. Weath. Rev. », 60, 1932, pp. 242-246, Washington.

(3) Visser S. W., *Sunspots and halos at Batavia*, « Beitr. Geoph. », 32, 1931, pp. 192-201, Leipzig.

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found that halo-days at Batavia decrease as the sunspot relative number increases from 0 to 90, but above that point they again increase. SEKIGUTI (1) studied the rise of temperature at stations in central Japan on normal days. After allowing for disturbing factors, he calculated that the rise between 6h. and 14h. is rather small when the sun's surface is inactive but increases rather suddenly as the solar activity increases. For still greater solar activity the rise becomes less again and continues to decrease as the sunspot area increases. Sekiguti thought that the effect might be indirect, possibly through a change of the transmission coefficient in high latitudes.

The double sunspot cycle or Hale period of 22-23 years has also been widely recognised, by S. HANZLIK (2) in the mean temperature of the lowest 3 km.; by A. PEPPLER (3) in the meridional pressure gradient over the North Atlantic; by A. E. DOUGLASS (4) in annual rings of tree-growth, and by C. E. P. BROOKS (5) in the Nile flood.

No important additions have been made to our knowledge of the relations between sunspot numbers and the distribution of mean annual temperature. Variations of temperature from day to day were studied by K. F. WASSERFALL (6). In 1916 the tendency of sunspots to concentrate about one stationary meridian was specially marked; the secondary area which is usually found about 180° from the main area was not well developed. In that year the daily mean temperatures of Oslo

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(1) SEKIGUTI R., *An attempt to detect a direct effect of the solar activity on the air temperature at some stations in the central part of Japan*, « Mem. Imp. Marine Obs. », 3, n. 1, 1926, pp. 1-21, Kobe.

(2) HANZLIK ST., *Der Temperatureffekt der Luftschichten der Erde in seiner Beziehung zu der Sonnenfleckenperiode*, « Beitr. Geoph. », 32, 1931, pp. 226-230, Leipzig.

(3) PEPPLER A., *Energieschwankungen der nordatlantischen Zirkulation und Sonnenflecken*, 1881-1923, « Beitr. Geoph. », 29, 1931, pp. 187-200, Leipzig.

(4) *Symposium on Climatic Cycles*, « Proc. Nat. Acad. Sci. », 19, 1933, pp. 349-385, Washington.

(5) BROOKS C. E. P., *Periodicities in the Nile Flood*, « Mem. R. Meteor. Soc. », 2, n. 12, 1928, London.

(6) WASSERFALL K. F., *On the relation between the rotation of the sun and variations of atmospheric temperature*, « Noerske Videnskamps-Akad., Geofys. Publ. », 5, n. 10, 1929, Oslo.

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showed oscillations of 27.3 and 13.6 days, with amplitudes of 3.9° and 4.7°C.

Several investigations have been made into the relations between solar changes and atmospheric pressure. S. HANZLIK (1) found an eleven year cycle of mean pressure opposed to the sunspot cycle in south-west Asia, India and further India and most of Australia, the latter area probably extending across the Indian Ocean to East Africa. The pressure cycle and sunspot cycles agreed over the tropical Pacific and part of South America. In most temperate regions the sign of the relationship changes from one sunspot cycle to the next, again showing the Hale effect. H. H. CLAYTON (2) considered that when solar activity, as indicated by spots and radiation values, increases, pressure falls in the equatorial belt and the polar regions and rises in middle latitudes, the general effect being a strengthening of the atmospheric circulation, but the zonal regularity of these changes is affected by the distribution of land and water and by seasonal effects. A. JATHO (3) stated that the relationship was best shown in regions of barometric calm, such as the equatorial zone, and the winter anticyclones. C. J. KULLMER (4) showed that near sunspot maxima the tracks of barometric depressions across the United States are on the whole more northerly than near sunspot minima. C. E. P. BROOKS (5) could discover no definite relation between the sunspot cycle and the distribution of pressure over western Europe, and S. S. VISHER (6) found no relation between sunspots and the annual frequency of tropical cyclones in the Pacific.

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(1) HANZLIK ST., *Der Luftdruckeffekt der Sonnenfleckenperiode*, « Beitr. Geoph. », 28, 1930, pp. 114-125 ; 29, 1931, pp. 138-155, Leipzig.

(2) CLAYTON H. H., *The atmosphere and the sun.*, « Smiths. Inst., Misc. Coll. », 82, n. 7, 1930, Washington.

(3) JATHO A., *La correlacion de la pression atmosferica y de las precipitaciones con las manchas solares*, « An. Soc. Cient. Argent. », 111, 1931, pp. 209-233 ; 295-304, Buenos Aires.

(4) KULLMER C. J., *The latitude shift of the storm track in the 11-year solar period.*, « Smiths. Inst , Misc. Coll. », 89, n. 2, 1933, Washington.

(5) BROOKS C. E. P., *Sunspots and the distribution of pressure over western Europe*, « Air Ministry, Meteor. Office, Prof. Notes », 4, n. 49, 1928, London.

(6) VISHER S. S., *Sunspots and the frequency of tropical cyclones*, « Amer. J. Sci. », 8, 1924, pp. 312-316, New Haven, Conn.

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O. v. u. z. AUFSESS (1) from an analysis of daily weather charts considered that when an effective radiating region appears on the sun an anticyclonic system often advances from the sub-tropical high (usually the Azores high) and if the effective solar region persists it spreads across Europe from west to east but if the effective region disappears, the anticyclone breaks up. Outbreaks of cold air masses and resulting rises of pressure can occur when no effective radiating areas are visible on the sun.

J. M. STAGG (2) showed that on magnetically quiet days the diurnal variation of pressure at Aberdeen was abnormal, the morning maximum being intensified and the evening maximum weakened.

A. JATHO (3, p. 149) found that the relation between sunspots and rainfall is best seen where there is either a well defined regime of rain-bearing winds or an ascensional movement of air due to solar radiation. E. T. QUAYLE (3) discovered a positive relation between the sunspot cycle and annual rainfall in Australia, except in the centre where the effect is reversed, probably because of retardation. In New Zealand E. KIDSON (4) described a positive relation between sunspots and rainfall over the whole of North Island and the northern part of South Island. In the Canterbury and Otago Provinces on the lee side of South Island the relationship was reversed.

A. SEPTER (5) investigated the annual frequency of thunderstorms at 229 stations in Siberia from 1888 to 1924, and found a very close positive relation to sunspot relative numbers. In continuation of this work, C. E. P. BROOKS (6) examined the relation between the sunspot cycle and the annual fre-

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(1) AUFSESS, O. v. u. z., *Kosmische Einflusse auf die Luftdruck-verteilung über Mitteleuropa*, « D. Met. Jahrb. Bayern », 1921, 43 (1922), pp. H 1-10 ; 1925, 47 (1926), pp. H 1-5, München.

(2) STAGG J. M., *Atmospheric pressure and the state of the earth's magnetism*, « Nature », 127, 1931, p. 402, London.

(3) QUAYLE E. T., *Sunspots and Australian rainfall*, « Proc. R. Soc. Victoria », 37, 1925, pp. 131-143, Melbourne.

(4) KIDSON E., *Sunspot numbers and annual rainfall in New Zealand.*, « J. Sci. Techn. », 10, 1928, pp. 90-97, Wellington.

(5) SEPTER A., *Sonnenflecken und Gewitter in Sibirien*, « Met. Zs. », 43, 1926, pp. 229-231, Braunschweig.

(6) BROOKS C. E. P., *The variation of the annual frequency of thunderstorms in relation to sunspots*, « Q. J. R. Meteor. Soc. », 60, 1934, pp. 153-165, London.

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quency of thunderstorms over the world as a whole, and found that this is positive in low and in high northern latitudes but is slight in middle latitudes. In low latitudes the variations of thunderstorms lag about five months behind the variations of sunspots but in high latitudes the changes are synchronous. Over the earth as a whole the frequency of thunderstorms during the sunspot cycle varies by about 11 per cent on either side of the mean.

Generally speaking, these various results support or are consistent with the hypothesis that the intensity of the atmospheric circulation varies with the number of sunspots, but the relationship is complicated, both by the difference between alternate sunspot cycles (Hale effect) and by secondary effects produced within the earth's atmosphere.

The idea of solar control has been extended by W. B. SCHOSTAKOWITSCH (1) and H. W. CLOUGH (2) to include nearly all terrestrial phenomena directly or remotely dependent on weather — severe winters, lake and river levels, glacial records, tree rings, harvest, wheat prices, death-rate, economic indices and even the frequency of earthquakes and volcanic eruptions, nearly all of which show periodicities approximating to those of sunspots, and Schostakowitsch has constructed a chain of causation between solar variations and various terrestrial phenomena, ending with historical events.

There has been much activity in studying the relations between solar variations and changes of climate during geological times. The studies fall into two groups, those which postulate variations in the radiation given out by the sun itself, and those which calculate the effect of changes in the relative positions of the earth and sun, the actual solar radiation being supposed constant.

E. HUNTINGTON and S. S. VISHER (3) related climatic changes on the geological scale to variations of solar radiation as

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(1) SCHOSTAKOWITSCH W. B., *Periodische Schwankungen in den Naturerscheinungen*, « Beitr. Geoph. », 30, 1931, pp. 281-335, Leipzig.

(2) CLOUGH H. W., *The 11-year sunspot period, secular periods of solar activity, and synchronous variations in terrestrial phenomena*, «Mon. Weather. Rev. », 60, 1933, pp. 99-108, Washington.

(3) HUNTINGTON E. and VISHER S. S., *Climatic changes*, New Haven « Yale University Press », and London « Oxford University Press », 1922.

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shown by the number of sunspots. Increased solar activity is considered to result in increased storminess, together with some displacement of the storm tracks towards the equator. The greater vertical movement of the air associated with the increased storminess, and the greater evaporation by stronger winds over the oceans, carry greater quantities of heat from the earth's surface to the higher levels of the atmosphere, where nearly half is lost by radiation to space. Such a period of increased solar activity is considered to account for the Quaternary glaciation, and another, possibly, for the Permo-Carboniferous glaciation, in which the storm tracks lay very far south while higher latitudes were unglaciated because of insufficient precipitation. Periods of slight solar activity and few sunspots had slight storminess with steady winds from low to high latitudes; hence they were mild and equable over the whole earth. The authors consider that the changes of storminess may not be due entirely to heat radiation but that some other form, possibly electrical, may also be involved.

G. C. SIMPSON (1) pointed out that the result of an increase of solar radiation is an increase of evaporation, cloud and precipitation over the earth and only a slight increase of temperature. On mountains and in polar regions the increased precipitation includes an increase of snowfall with a consequent growth of glaciers and ice-sheets resulting in a glacial period. As the sun's radiation increases still further, however, the small increments of warmth finally turn the snow to rain and the glaciers melt, giving a warm « interglacial period ». After the cycle of solar radiation reaches its crest and begins to wane, the same changes occur in reverse order, giving a second glacial period. Finally radiation falls to a minimum, the earth is cold, there is little evaporation and consequently little snowfall. The ice sheets die from lack of nourishment, giving a cold interglacial period. Two complete cycles of radiation would give four glacial and three interglacial periods: of the latter the first and third would be short, warm and rainy, the second long and dry, agreeing with the succession found in the Alps. Outside the glaciated regions each pair of glacial

(1) SIMPSON G. C., *Past climates*, Alexander Pedler Lecture, 1929. « Mem. Lit. Phil. Soc. », 74, 1929-30, pp. 1-34, Manchester.

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periods and the intervening « warm » interglacial should be represented by a « pluvial » period, which agrees with the succession found in Africa.

In a recent paper SIMPSON (1) examined the geological evidence of climatic changes over the whole world during the Quaternary in greater detail, and estimated that at the maximum of the solar radiation the temperature was between 5°C and 10°C, warmer than at present, and the cloud amount was increased from the present 0.5 to between 0.7 and 0.8. From these data he calculated that the sun is a variable star with an amplitude of 20 per cent (range 40 per cent) in the intensity of the radiation and a period of the order of 10^5 years.

The astronomical factors include slow changes in the obliquity of the ecliptic, in the eccentricity of the earth's orbit, and in the season in which perihelion falls (precession of the equinoxes). These factors cause variations in the distribution among the seasons of the heat received from the sun in different latitudes, even though the total radiation from the sun remains unchanged. The result would be a variation of climate from the oceanic type, with mild winters and cool summers, to the continental type, with relatively severe winters and short hot summers.

An Eocene lake deposit in Colorado and Utah which probably shows the precession of the equinoxes was described by W. H. BRADLEY (2). The deposits consist of an enormous number of extremely thin *laminae*, arranged in pairs ; each pair, less than a millimetre thick, represents the accumulation of one year, and the total thickness of 2,000 feet represents the passage of more than 600,000 years. The thickness of the layers is not constant but shows well marked periodicities of a little less than 12 years, 50 years and 21,630 $\pm$ 100 years. The first of these is attributed to the sunspot cycle, the last to the precession of the equinoxes. This cycle is shown by a change, repeated 16 times, from oil shale to marlstone, and Bradley suggests that a series of years with long cool winters and short hot summers would favour the formation of oil shales, poor

(1) SIMPSON G. C., *World climate during the Quaternary period*, « Q. J. R. Meteor. Soc. », 60, 1934, pp. 425-478, London.

(2) BRADLEY W. H., *The varves and climate of the Green River Epoch.*, « U. S. Geol. Surv. », Prof. Paper 158E, 1929, Washington.

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in calcite but rich organically, while years with a more uniform temperature would favour the calcite and produce marlstones. This is the succession which would be expected to result from the cycle of the precession of the equinoxes.

When all three of the astronomical factors are considered, variations in the seasonal range of heat received in any one latitude become more complicated. They have been calculated for the last 600,000 years independently by M. MILANKOVITSCH (1) and W. KÖPPEN (2). The results are in substantial agreement, and show a number of periods during which the radiation reaching the higher latitudes of the northern hemisphere in the summer half-year fell to well marked minima. These minima of summer heat are considered to have caused glaciers and ice-sheets to develop and extend, and in recent years several papers have been published by European glaciologists (e. g. SOERGEL, GRAHMANN, EBERL and BECK) in which the various glacial advances and retreats in central Germany and the foothills of the northern Alps are closely correlated with the minima and maxima of the curve of summer radiation.

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(1) MILANKOVITSCH M., *Mathematische Klimalehre und astronomische Theorie der Klimaschwankungen*, « Handb. d. Klimatologie von Köppen und Geiger », Bd. I, Teil A, Berlin.

(2) KÖPPEN W., *Schwankungen der Sonnenstrahlung seit 135000 Jahren und deren Folgen*, « Beitr. Geoph. », 31, 1931, pp. 231-239, Leipzig.

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TABLE DES MATIÈRES

Quatrième rapport au conseil international des Unions Scientifiques, par G. ABETTI ..... Pag. 5

Introduction..... ivi
Discussion sur les relations solaires et terrestres..... 9
Année polaire..... 14
Phénomènes solaires. Cycles. Rayonnement solaire..... 15
Conditions magnétiques de la terre et courants terrestres. 18
Aurores polaires..... 22
Propagation des ondes radioélectriques..... 23
Absorption dans la haute atmosphère terrestre..... 25
Rayonnement cosmique..... 28
Lumière du ciel nocturne..... 30
Variations météorologiques et climatologiques sur la terre. 31

Note sur les progrès récents dans l'étude des relations entre les phénomènes solaires et terrestres, par CH. FABRY.... 35

Radiation solaire, phénomènes solaires..... 39

On the solar radiation in the ultra-violet region of the spectrum, by W. E. BERNHEIMER..... 41
Coopération internationale pour la surveillance continue de la chromosphère solaire avec le spectrohélioscope, par L. D'AZAMBUJA..... 50

Conditions magnétiques de la terre et courants terrestres..... 53

Solar influences on the earth's magnetism and on the upper atmosphere, by S. CHAPMAN..... 55

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Researches of the department of terrestrial magnetism of the Carnegie Institution of Washington bearing on solar activity and the earth's magnetic and electric fields, 1932-1934, by J. A. FLEMING.....Pag. 60
Review of certain contributions to cosmic electricity and magnetism, by R. GUNN..... 69
Sur l'intervalle de temps entre les phénomènes solaires et les perturbations magnétiques terrestres, par CH. MAURAIN. 73
Solar activity and its relation to terrestrial-magnetic phenomena, by A. G. MCNISH..... 76
Prominences, the ultra-violet radiation of the sun and the diurnal change of terrestrial magnetism, by E. J. PEREPELKIN..... 82

Aurores polaires..... 87

Investigations on aurora at the auroral observatory, Tromsö, Norway, by L. HARANG..... 89
The production of the auroral spectrum, by J. KAPLAN.... 92

Propagation des ondes radioélectriques..... 99

Variations of upper atmospheric ionization, by L. V. BERKNER..... 101

Absorption dans la haute atmosphère terrestre..... 107

Absorption du rayonnement ultraviolet solaire de courte longueur d'onde par l'oxygène des couches supérieures de l'atmosphère, par D. CHALONGE et E. VASSY..... 109
Sur la production d'ozone atmosphérique par les électrons solaires pendant l'hiver polaire, par D. BARBIER, D. CHALONGE et E. VASSY..... 111
Spectrophotométrie visuelle du soleil ; etude visuelle de l'ozone atmosphérique, par J. GAUZIT..... 112
New investigations on radiation at the Arosa light-climatic observatory, by F. W. P. GÖTZ..... 116
Wave length measurements and analysis of the emission spectrum of the upper atmosphere, by L. A. SOMMER.... 119

Rayonnement cosmique..... 125

Cosmic ultra-radiation and the flocculi of the sun, by A. CORLIN..... 127

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Lumière du ciel nocturne.....Pag. 133

Analyse spectrale et polarisation de la lumière du ciel nocturne, par J. DUFAY et J. CABANNES..... 135

Light of the night-sky, by J. KAPLAN..... 140

Variations météorologiques et climatologiques sur la terre..... 145

The relations of solar and meteorological phenomena : a summary of the results from 1925 to 1934 inclusive, by C. E. P. BROOKS..... 147

Liste des Membres de la Commission..... 155

Table des Matières 157

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